U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-299 355

Lake Apopka Restoration Project, Lake and Orange Counties, Florida

(U.S.) Environmental Protection Agency, Atlanta, GA Region IV

Dec 78

BIBLIOGRAPHIC DATA SHEET

1. Report No. EPA 904/9-78-027

2.

3. Recipient's Accession No. PB299355

4. Title and Subtitle
Lake Apopka Restoration Project Lake & Orange Counties, Florida Draft EIS

5. Report Date December 1978

6.

7. Author(s)
EIS Preparation Section, EIS Branch, EPA, Region IV

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
EIS Branch, Region IV, EPA
345 Courtland Street, N.E.
Atlanta, GA 30308

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
Same.

13. Type of Report & Period Covered DRAFT

14.

15. Supplementary Notes

16. Abstracts

Lake Apopka is a 12,500 lectare (31,000 acre) lake located in central Florida, approximately 25 km (15 mi) northwest of Orlando. Throughout the first half of this century Lake Apopka contained clear water and luxuriant vegetation and was noted for its excellent bass fishing. Today it is a highly eutrophic lake and experiences continual algal blooms. Rough fish are now the dominant species in the lake. The purpose of the EIS is to meet the objectives of XXXXX NEPA. The overall goal of the project is to stop the continuing degradation of the lake's waters and to restore Lake Apopka as a quality natural resource. The Final EIS summarizes the Draft EIS and addresses comments received by interested governmental agencies, environmental groups and concerned citizens.

17. Key Words and Document Analysis. 17a. Descriptors

Eutrophic
Consolidation
Drawdown
Nutrient diversion (abatement)
NEPA (National Environmental Policy Act)

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page UNCLASSIFIED

21. No. of Pages 379

22. Price PcA17
MFA01

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

United States
Environmental Protection
Agency

Region 4
345 Courtland Street, NE
Atlanta GA 30308

EPA 904/9-78-027
December 1978

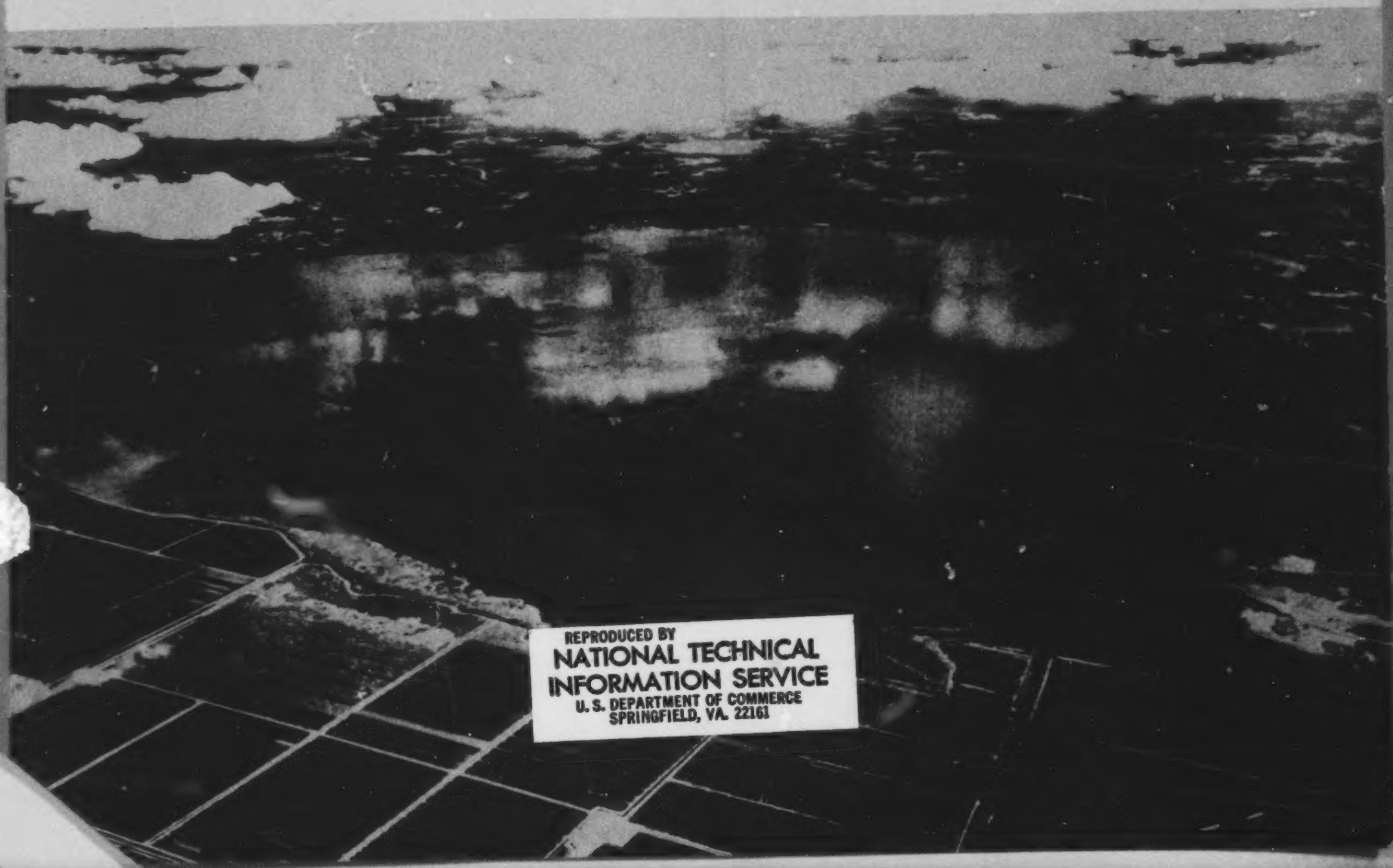
PB 299355

Clean Lakes

Environmental Impact Statement

Draft

Lake Apopka Restoration Project Lake & Orange Counties Florida



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DRAFT ENVIRONMENTAL IMPACT STATEMENT

FOR

LAKE APOPKA RESTORATION PROJECT
LAKE AND ORANGE COUNTIES, FLORIDA

Prepared By

U.S. Environmental Protection Agency
Region IV
Atlanta, Georgia 30308

With Technical Assistance By

Florida Department of Environmental Regulation
Bureau of Water Management
Water Resources Restoration and Preservation Section

RESPONSIBLE OFFICIAL:

John C. White
John C. White
Regional Administrator

January 29, 1979
Date

This document was written with technical assistance by the Florida Department of Environmental Regulation and was reviewed by the department prior to publication. However, the state has not yet made a decision as to whether or not to pursue project construction. The mention of trade names or commercial products does not constitute endorsement or recommendation for use, by either the Environmental Protection Agency or the Department of Environmental Regulation.

TABLE OF CONTENTS

SUMMARY vi

SECTION 1 INTRODUCTION 1

- Lake Description and History 1
- Citizen Concerns and Issues 6
- Clean Lakes Program 8
- Project Objectives 10

SECTION 2 EXISTING CONDITIONS 11

- Meteorology and Climatology 11
- Topography 16
- Geology 20
- Soils 25
- Hydrology 29
- Water Quality 39
- Biology 45
- Air Quality 70
- Land Uses 74
- Population Projections and Characteristics and Economic Forecasts 80
- Cultural Features 91
- Other Programs in the Area 98

SECTION 3 ALTERNATIVES AND THEIR EFFECTS

- No Action 100
- Enhanced Fluctuation 101
- Chemical Sedimentation 102
- Dredging 104
- Nutrient Diversion 106
- Flushing 107
- Aeration 108
- Drawdown and Sediment Consolidation 110

SECTION 4 DESCRIPTION OF SELECTED ALTERNATIVE 114

- Selection 114
- Constraints 114
- Description 116

SECTION 5 IMPACTS OF PROPOSED ALTERNATIVE AND MITIGATIVE STEPS FOR IDENTIFIED ADVERSE IMPACTS 133

Water Quality Impacts and Mitigative Steps 133
Biological Impacts and Mitigative Steps 138
Physical and Socioeconomic Impacts and Mitigative Steps 152
Meteorological Impacts and Mitigative Steps 169
Impacts of Increased Lake Beauclair Sedimentation and Subsequent Drawdown 171

SECTION 6 PUBLIC PARTICIPATION PROGRAM 177

SECTION 7 GLOSSARY 182

SECTION 8 LITERATURE CITED 190

APPENDIX A WATER QUALITY DATA A-1

APPENDIX B ENGINEERING DESIGN PLAN AND COST BREAKDOWN B-1

APPENDIX C ECONOMIC TRADE-OFFS ANALYSIS C-1

APPENDIX D FROST/FREEZE STUDY D-1

LIST OF TABLES

Table Number	Table	Page Number
1.1	20th Century History of Lake Apopka	4
1.2	History of Lake Apopka Clean Lakes Grant	9
2.1	Geologic Formations	22
2.2	Mean Monthly Net Input to Lake Apopka	31
2.3	Yearly Net Input to Lake Apopka	32
2.4	Discharge Rates Along Oklawaha Chain	37
2.5	Legal Desirable Lake Levels	38
2.6	Area Covered by Various Plants in Lake Apopka	47
2.7	Zooplankton Sampling in Lake Apopka	53
2.8	Invertebrates Collected in Lake Apopka	57
2.9	Fish Species Collected in Lake Apopka	59
2.10	Average Number, Kilograms, and Percentage Compositions for each Category of Fish Collected	60
2.11	Endangered, Threatened, Rare, or Special Concern Species in Oklawaha Chain	68
2.12	Ambient Air Quality Standards	70
2.13	Air Quality Readings, Orlando	71
2.14	Air Quality - Particulate Levels	72
2.15	Land Use - Oklawaha River Basin, 1970	74
2.16	Non-agricultural Land Use in Hectares, 1970-1990	77
2.17	Populations for Lake County and Florida	80
2.18	Natural Growth and Net Migration, Lake County	82
2.19	Population Projections for Lake County and the Oklawaha River Basin	82
2.20	Population Projections for Specific Divisions in the Oklawaha Basin	83

Table Number	Table	Page Number
2.21	Age Group Population Projections: Oklawaha River Basin Planning Area, 1970-1990	84
2.22	Income of Families, Florida and Lake County	85
2.23	Housing Values, 1970. Lake County and Florida	87
2.24	Lake County Farm Income as Percent of Total Labor and Proprietor's Income	88
2.25	Lake County Earnings by Broad Industrial Sector	90
2.26	Unemployment Trends, Lake County	90
2.27	Recreation Participation Survey, East Central Florida	94
2.28	Historical/Archeological Sites Near Project Area	97
4.1	Comparison of Restoration Techniques	115
5.1	Pros and Cons of Terrestrial Weed Removal	142
6.1	Members of Citizens' Review Committee & Alternates	178

LIST OF FIGURES

Figure Number	Title	Page Number
1.1	Map of Project Location	2
2.1	Yearly Temperature Pattern	12
2.2	Annual Rainfall	14
2.3	Average Monthly Rainfall	15
2.4	Major Physiographic Regions of Florida	17
2.5	Physiographic Landforms of Oklawaha Basin	18
2.6	Upper Oklawaha River Drainage Basin	21
2.7	General Soils Associations	26
2.8	Chain of Lakes and Water Control Structures	36
2.9	Location of STORET Sampling Stations	41
2.10	Average Number of Substrate Organisms	56
2.11	Physical and Ecological Events Leading to Lake Apopka's Current Condition	62
2.12	Food Web for Lake Apopka	65
2.13	Particulate Levels for Leesburg and Okahumpka	73
2.14	Land Use and Land Cover, 1972	76
2.15	Oklawaha River Basin Planning Area	81
2.16	Population Pyramids - Oklawaha River Basin Planning Area, 1970-1990	84
4.1	Construction Sites for Lake Apopka Drawdown Project	118
4.2	Path of Dora Canal Transmission Main Bypass	121

SUMMARY

DRAFT ENVIRONMENTAL IMPACT STATEMENT

LAKE APOPKA RESTORATION PROJECT

The purpose of this draft Environmental Impact Statement (DEIS) is to meet the objectives of the National Environmental Policy Act (NEPA). NEPA directs federal agencies to prepare a statement which identifies all reasonable alternatives and which evaluates the environmental impacts of these alternatives. NEPA then directs federal decision makers to incorporate this environmental evaluation into the decision making process. This document has been prepared in accordance with these directives.

The action for which this document has been prepared is the restoration of Lake Apopka. The overall goal of the restoration project is to stop the continuing degradation of the lake's waters and to restore Lake Apopka as a quality natural resource.

Four primary objectives have been identified in attaining this goal. The first objective is to improve the water quality of Lake Apopka to meet Class III standards as defined by Chapter 17-3, Florida Administrative Code. Secondly, the project aims to improve water quality in the entire Upper Oklawaha Chain of Lakes by restoring the headwaters of this chain (Lake Apopka). The third objective is to provide aquatic habitats which are capable of supporting game fish and wildlife, with a subsequent reduction in rough fish. The final objective involves making Lake Apopka suitable for water-contact recreational opportunities. These four objectives are the criteria by which the success of the restoration project will be judged.

Lake Apopka is a 12,500-hectare (31,000-acre) lake located in central Florida, approximately 25 km (15 mi) northwest of Orlando. Although Apopka has a large surface area, it is a shallow lake, averaging less than 2 m (6.6 ft) in depth. Throughout the first half of this century Lake Apopka contained clear water and luxuriant vegetation and was noted for its excellent bass fishing. Today it is a highly eutrophic lake and experiences continual algal blooms. About 90 percent of the lake bottom is covered with organic deposits; in some places this muck is more than 15 m (50 ft) deep. Unconsolidated sediments are also easily suspended in the water column, thereby causing extreme turbidity problems. Suitable habitats for game fish, rooted aquatic vegetation, and benthic invertebrates have been reduced to fractions of their previous extent. Rough fish such as shad, gar, and catfish are now the dominant species in Lake Apopka.

Massive nutrient overloading is the main cause of Lake Apopka's demise as a quality resource. Sewage discharges from Winter Garden, irrigation water pumped from the muck farms, and citrus processing plant wastes were major contributors of nutrients. A 1947 hurricane uprooted much of the lake's vegetation, releasing more nutrients into the water, and was followed shortly thereafter by the lake's first algal bloom. Subsequent hyacinth sprayings and selective rough fish poisonings added to the problem because the dead plants and fish were not removed from the lake. These operations, in conjunction with the lake level stabilization program begun in 1952, stifled any chance for a natural recovery of the lake's ecosystem.

Measures to improve water quality, restore the fisheries, and provide recreational opportunities have been outlined in this DEIS. DER is the primary project sponsor and has contracted numerous studies through universities and other agencies to analyze specific problems related to the restoration project. Frost/freeze, hydrological, limnological, engineering, and legal studies have all been completed through DER contracts. Furthermore, the engineering firm of Ross, Saarinen, Bolton, and Wilder (RSB&W) was retained to study the feasibility and probability of success of the recommended restoration action.

Numerous restoration alternatives were considered and analyzed in this DEIS. The "no action" alternative would cause no significant changes in Lake Apopka's present condition and is not recommended. Algal blooms would persist and unconsolidated sediments would maintain high turbidity levels and deter the growth of desirable rooted macrophytes. The other considered alternatives included enhanced fluctuation of lake levels, chemical sedimentation, dredging, nutrient diversion, flushing, aeration, and drawdown. Of these, only dredging and drawdown would yield the desired results. Dredging is prohibitively expensive for a 12,500-hectare lake; therefore, drawdown is being recommended as the desired alternative.

Nutrient diversion (abatement), and enhanced fluctuation are recommended as secondary programs to complement the drawdown. Nutrient abatement is a prerequisite for any lake restoration. If the causes of the lake's present deterioration are not reduced, the benefits of the drawdown restoration will be short-lived. A $9 million nutrient abatement program for Lake Apopka has been implemented and will be completed prior to the proposed drawdown. To avoid future deterioration of Lake Apopka bottom conditions due to unavoidable nutrient inputs, the lake should also experience fluctuating water levels. Such fluctuations simulate natural conditions in most lakes and provide beneficial maintenance of the littoral zone.

A drawdown simulates an extreme drought. As the lake is drained, the unconsolidated sediments are exposed, causing them to compact and stabilize into a firm substrate. This consolidated muck provides a base for rooted aquatic macrophytes, suitable material for game fish breeding, and a habitat for an increased diversity of benthic invertebrates. Sediment consolidation also lowers turbidity levels and retards nutrient releases from the sediments to the water column. These results will improve water quality and increase littoral zone vegetation, thereby promoting a healthy sportfishery.

The drawdown process will operate within strict constraints to avoid any damage to downstream water quality or surrounding physical and cultural developments. Preliminary engineering designs indicate the entire project, from initial construction to cleanup operations, will require approximately two years. Installation of coffer dams, access roads, pumping stations, a settling basin, canals, and other necessary facilities will take several months. A gravity drawdown from the lake's average level of 20.4 m (67 ft) msl to 19.8 m (64 ft) msl will overlap this construction period and will be followed by a three-month pumped drawdown to 17.7 m (58 ft) msl. The lake will be held at this elevation for at least two months and will then be refilled using water which will have been stored in downstream lakes. This refill period will take up to four months, as will the clean-up operation and removal of equipment. Monitoring of water quality and bottom conditions will be conducted for an undetermined period following refill.

Because an effective on-land sedimentation basin would be extremely expensive, an in-lake basin will be used during the Lake Apopka drawdown. Although this type of basin is economically more feasible, some sediments are likely to pass downstream and settle out in Lake Beauclair. Therefore, to ensure that no damage occurs to downstream waters, a drawdown restoration of Lake Beauclair will be conducted following the Apopka drawdown. Together, these drawdowns constitute the proposed Lake Apopka restoration project which is analyzed in this DEIS. The effects of such an undertaking and steps to mitigate potential adverse impacts are discussed following a detailed description of the recommended alternative. The final section of the DEIS explains the public involvement program related to the project.

The following impacts can be expected if the drawdown is implemented. Most of the beneficial effects are long-lasting, but will not occur until the restoration project is completed. The majority of adverse impacts are temporary in nature and will be rectified upon project completion. Appendix C contains a benefit-cost analysis which explains the economic impacts in greater detail.

Adverse Impacts

1. Exposed bottom sediments, concentrated decaying biomass, and flooded terrestrial vegetation will cause temporary, aesthetically unpleasing conditions and odors.
2. Phytoplankton populations in downstream lakes may increase during drawdown and holddown.
3. Some aquatic animals in Lakes Apopka and Beauclair will die due to decreased food and reproduction habitats.

4. Fish will die as they become extremely concentrated in the remaining pools of water. Downstream fish kills are possible but not expected.

5. Alligators (a threatened species) will migrate to adjacent lakes; those remaining will lose a year's brood.

6. The consolidating lake bottom will increase mosquito breeding habitat, requiring increased spraying.

7. The water quality of downstream lakes may be temporarily degraded due to increased nutrient levels and reduced dissolved oxygen concentrations.

8. Construction activities will cause temporary soil erosion, noise pollution, and air pollution.

9. A restored Lake Apopka may experience an increased demand for lakeside residential development. Such pressure could result in encroachment on citrus orchards and increased soil erosion.

10. Several small wetland areas may be temporarily disrupted by dredging, spoil disposal, or construction activities.

Beneficial Effects

1. Desirable macrophytic growth will increase in a restored Lake Apopka. These plants will compete with phytoplankton for available nutrients and thus reduce algal blooms in the lake.

2. Existing algae will shift from predominantly blue-green species to less noxious green species.

3. Water quality will improve in Lake Apopka, thereby restoring and enhancing lake ecosystems. Similar effects will occur in downstream lakes as restored Apopka water "flushes" through the chain of lakes.

4. Forested wetlands adjacent to the lake may experience increased growth of new seedlings due to the fluctuating water levels.

5. The suspended muck sediments in Lake Apopka will consolidate, thereby reducing turbidity levels and decreasing exchange of nutrients from suspended sediments to the water column.

6. Fish-eating birds, including the bald eagle (threatened species), osprey (threatened species), and wood stork (endangered species)

will experience increased food supplies as fish are concentrated in the remaining water.

7. Total standing crops of both game and rough fish species will multiply; however, the ratio of rough fish to game fish will decrease.

8. Phosphate and nitrogen levels in the lake should be reduced by approximately one-half their current levels within six months to five years after completion of the project.

9. Restored Lakes Apopka and Beauclair will experience few, if any, noxious odor problems and periodic fish kills, thereby improving the lakes' aesthetic appeal.

10. Sportfishing and other recreational opportunities will increase in Lake Apopka and throughout the chain as water quality improves.

11. Commercial fishermen will experience greater harvests of catfish as standing crops increase in the restored lakes.

12. The local economy will experience a boost during drawdown due to construction activity associated with the project and its demand on local labor and materials.

13. Further long-range economic benefits will result from the re-establishment of fish camps and other recreation-oriented businesses.

14. A comprehensive inventory of historical and archeological sites will be conducted on certain areas of the Oklawaha Basin.

15. The entire chain of lakes will experience aesthetic improvements as water quality improves and Lake Apopka loses its tarnished image.

16. Property values will increase as the perceived utility of lakeside parcels is enhanced.

17. Implementation of the project will advance scientific understanding of lake ecosystems and the impacts of drawdown as a lake restoration technique.

18. Lakeside citrus orchards will receive increased frost/freeze protection due to the increased volume of the lake following muck consolidation.

Appropriate Federal and State Agencies will receive copies of this DEIS, as will interested groups and individuals. Their comments and questions will receive adequate attention and will be addressed in the Final EIS.

SECTION 1

INTRODUCTION

Until the 1950's, Lake Apopka attracted national attention as a bass fishing lake. Lake Apopka now attracts state-wide attention as an example of the worst effects of cultural eutrophication*.[1] In less than a generation the lake was changed from a resource of high economic and aesthetic value into a problem likely requiring complex and expensive solutions. This document evaluates the environmental consequences of various alternative measures for correcting Lake Apopka's problems.

Lake Description and History

Lake Apopka is located in Central Florida approximately 25 km (15 miles) northwest of Orlando (Figure 1.1). At 12,500 hectares (31,000 acres, 51 square miles) the lake is the fourth largest in Florida. Apopka is shallow (average depth < 2 m) and heads a chain of lakes including (in progressive order) Beauclair, Dora, Eustis, and Griffin. This chain forms the headwaters of the Oklawaha River, a major tributary of the St. Johns River. Thus, conditions in Lake Apopka can potentially affect bodies of water from Central Florida to extreme Northeast Florida.

The extensive organic deposits in Lake Apopka (15 m deep in some areas) suggest that the lake has long been highly productive, perhaps for hundreds of years. However, until the middle of this century, Lake

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[1] Technical language is deliberately minimized in this report, but the use of some technical terms is unavoidable. A glossary (pages 182-189) is provided for these terms. Each technical term is marked with an asterisk (*) upon first usage in the body of the report, and is defined in the sense that it is used within this EIS.

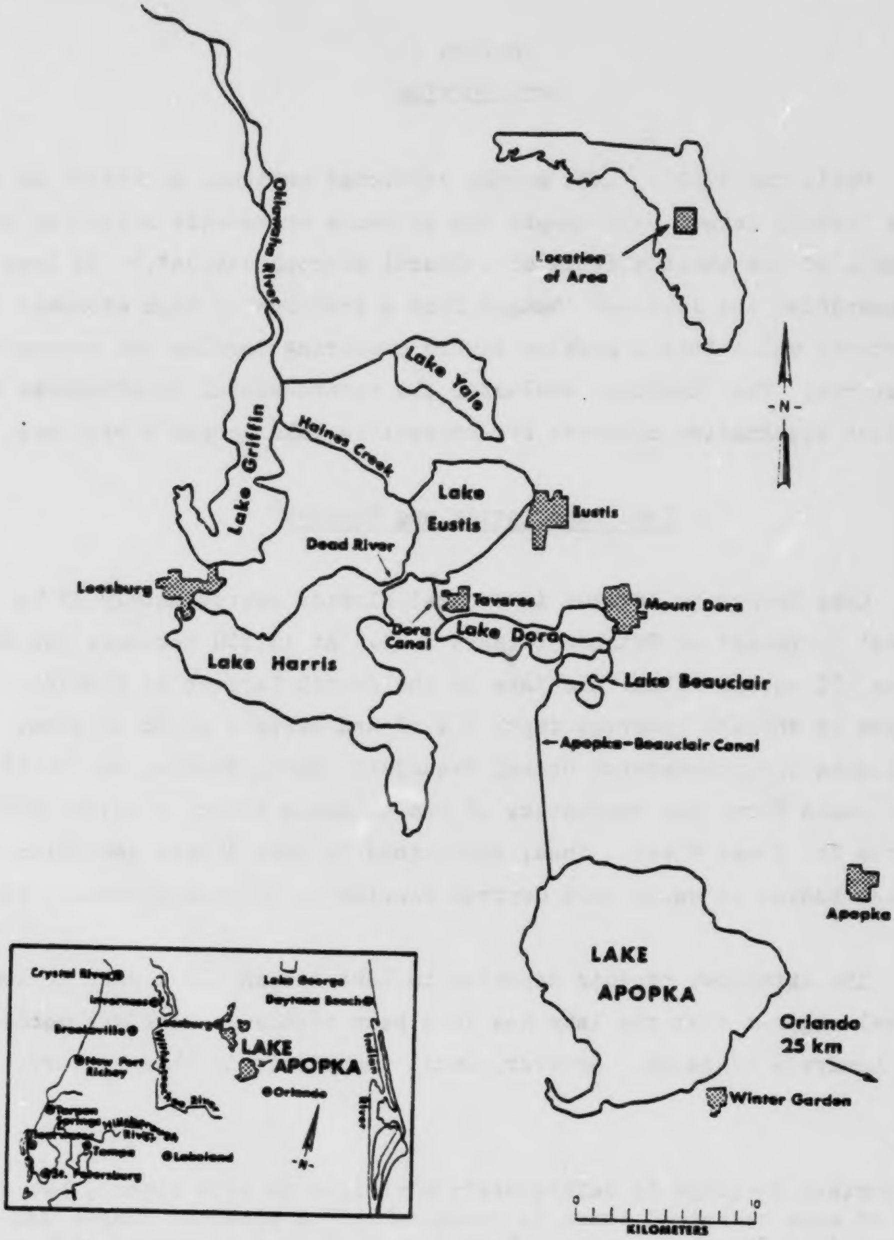
Oklawaha River
Lake Yale
Location of Area
-N-
Haines Creek
Lake Griffin
Lake Eustis
Eustis
Dead River
Leesburg
Tavares
Mount Dora
Dora Canal
Lake Dora
Lake Harris
Lake Beauclair
Apopka-Beauclair Canal
Apopka
LAKE APOPKA
Orlando 25 km
Winter Garden
Crystal River
Lake George
Daytona Beach
Inverness
Brooksville
Leesburg
LAKE APOPKA
New Port Richey
Orlando
Tarpon Springs
Tampa
Lakeland
St. Petersburg
-N-
0 10
KILOMETERS
0 5
MILES

Figure 1.1. Map of Project Location.

Apopka contained luxuriant vegetation and extrememly clear water (Clugston, 1963).[2] Local residents have confirmed reports that until the early 1950's, the lake supported an impressive gamefishery.

Lake Apopka is currently highly eutrophic* (Shannon and Brezonik, 1972). Perpetual algal blooms* occur in the lake, and loose unconsolidated sediments are periodically resuspended in the water column by wave action. This material causes extreme turbidity* and remains suspended for days. Rooted aquatic vegetation has all but disappeared from the lake as has the once-famous bass fishing. Rough fish such as shad and gar are now the dominant fish species.

Table 1.1 gives a summary of the events leading to the current condition of Lake Apopka. Nutrient* overloading is primarily responsible for the degraded condition of the lake, and most of these nutrients can be traced to three sources introduced during this century. The first, beginning in the 1920's, was sewage discharge from Winter Garden, located on the southeastern shore of the lake. The second, beginning in 1942, was discharge of irrigation water from muck farms on the northern shore of the lake. The third, beginning in 1948, was discharge from citrus concentrate operations by the Winter Garden Citrus Cooperative.

Prior to the 1940's, a vast (8000 hectares, 20,000 acres) marsh extended north from the lake. As part of the World War II food production effort, most of this marsh was drained and converted into highly productive farms. Lost with the marsh was its nutrient retention and assimilation capability. In addition nutrient-rich discharges of irrigation water backpumped into Lake Apopka from the farms significantly stressed the lake's ecosystem.

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[2] Supportive references will be provided in this document whenever possible. However, when references would be difficult for the reader to obtain (as in the case of memos, staff reports, and drafts), citations will not be given. Access to this information will be available to any interested reader through Florida DER.

Table 1.1. Summary of the 20th Century History of Lake Apopka.

1922-27	Sewage effluent from Winter Garden first discharged into lake.
1924	Waste water from preparation of fresh fruit first discharged into lake.
1942	Discharge from muck farms begins.
1947	September hurricane(s) destroyed large amounts of bottom vegetation. First algal bloom reported in October.
1948	Citrus concentrate waste first discharged into lake. Chemical control of water hyacinths attempted. Apopka-Beauclair Canal opened.
1948-1950	Rooted aquatic vegetation disappears. Frequent algal blooms.
1950-1955	Game fishing peaks.
1952	Lake water level stabilized by control structure placed in Apopka-Beauclair Canal.
1957	Rough fish estimated as 82% of fish population (by number).
1957-1959	Three separate selective poisonings killed a total of 9 million kg (20 million lbs) of shad.
1963	In May, gas embolism killed 4.5-9 million kg of rough fish and 0.2 million kg of game fish.
1970	Rough fish estimated as 82% of fish population (by number).
1971	Experimental gravity drawdown. Death of alligators, turtles, and fish attributed to Aeromonas (bacteria).
1976-present	Abatement of muck farm discharges.
1977	Discharge of citrus concentrate wastes ends. Winter Garden begins construction of tertiary sewage treatment plants.

Sources: Clugston, J.P., 1963. Lake Apopka, Florida-A Changing Lake and its Vegetation. Quat. Journal Florida Acad. Sci. 26:168-174.
Various staff reports and memos.

Apopka successfully withstood this stress until a September 1947 hurricane (or hurricanes) uprooted much of the lake's vegetation. The first known algal bloom in Lake Apopka occurred the following month, likely induced by nutrient release from suspended sediments and decomposing plants. Further blooms followed with increasing frequency. Attempts at chemical control of water hyacinths began in 1948, and nutrients released during decomposition of dead hyacinths contributed greatly to overenrichment of the lake.

By approximately 1950, rooted aquatic vegetation had disappeared from the lake, apparently as a result of shading by dense algal blooms. Recovery of this vegetation has since been thwarted by a lake water-level stabilization program which began in 1952. Florida Game and Fresh Water Fish Commission (FG&FWFC) biologists have amassed evidence supporting the importance of natural lake fluctuation in maintaining a vegetated littoral zone*.

Gamefishing in Lake Apopka actually improved in the late 1940's, reaching historical peaks in the early 1950's. Some of the energy from the decaying uprooted vegetation was likely transferred through fish food organisms into game fish production.

Since the early 1950's populations of game fish have declined with a corresponding increase in rough fish such as shad. By 1957 rough fish were estimated to compose 82 percent (by number) of the total fish population. This domination has persisted in spite of massive artificial and natural killings of shad. Three selective shad poisonings during 1957-1959 killed an estimated total of 9 million kg (20 million pounds) of shad. In May 1963, gas embolism was the suspected cause of death for 4.5-9 million kg of rough fish and more than 0.2 million kg of game fish. Gas embolism is the sudden obstruction of a blood vessel by an air bubble, and in this case apparently resulted from supersaturation* of the water with oxygen produced by photosynthesis.

Ironically, the attempts to control shad and water hyacinths may have contributed to a more rapid degradation of Lake Apopka. Killed fish were left in the lake to decay, and nutrients released during their decomposition apparently resulted in extensive algal blooms. FG&FWFC personnel estimate that the nitrogen and phosphorous available in deliberately killed shad and hyacinths exceeded by 1.5 times the total nitrogen and phosphorous added by the Winter Garden sewage treatment plant during the past 37 years.

Thus, Lake Apopka has become an example of some of the worst effects of cultural eutrophication. A lake of high natural productivity has been overstressed and, in consequence, has lost much of its utility to the citizens of the area.

Citizen Concerns and Issues

As the lake began to lose its aesthetic and recreational appeal, the citizens of the region reacted emotionally. The obvious targets of their frustration were those who were discharging pollutants into the lake. Citizens formed groups and began considering law suits against the muck farmers and others. One such suit became reality. The Florida Department of Pollution Control (DPC), predecessor agency to the Department of Environmental Regulation (DER), reacted swiftly by serving notices to the dischargers that plans to control pollution would have to be submitted to the department for approval, and compliance schedules would have to be met. By September 1972, the date of Florida's application for federal funding for the Apopka project, many of the major polluters were meeting state standards and all others had submitted plans to do so. As funding became available, these wastewater treatment programs got underway and future compliance appeared possible.

In 1971, even complacent residents around the lake became concerned, for suddenly the lake was a possible threat to human health. When dead alligators and turtles were found along the lake shore, officials came to the area to study the remains of the animals to determine if there were a virus or similar disease that could be transmitted to humans. Some residents blamed the kill on DPC's attempted gravity drawdown, while others cited years of man's tampering with the waterbody. Lake County's Pollution Control Officer warned that the lake had been in an "emergency" situation long before it became evident to the public. With newspapers flaunting photographs of dead alligators and headlines of a "mystery" disease, public sentiment ran high. State senators became actively involved in the program to restore Lake Apopka, and President Nixon was even asked to declare the lake a disaster area. Emergency funds did not become available; in fact, it was 1976 before federal money was finally released for the Lake Apopka project.

As state agencies reviewed various plans to restore Lake Apopka, citizen input was requested and received. A Lake Apopka Revitalization Committee was established in 1975. When the committee realized the broad scope of the project, it expanded into the Oklawaha River Basin Revitalization Committee.

Today, three years after the formation of that committee, citizens are concerned that the restoration project has been delayed so long that it may be forgotten. At a public meeting on March 7, 1978, when the decision to write an environmental impact statement was discussed and the time frame outlined, this frustration was loudly expressed. The presiding state and federal officials were told emphatically that the project should not be abandoned or even delayed, for the future of the entire Oklawaha chain of lakes is at stake.

As government officials attempt to bring about the culmination of a decade-long dream of a restored Lake Apopka, the various items of public concern must not be neglected. These worrisome items have been expressed in public meetings, newspaper interviews, and letters from interested private and public parties. The major theme of these items regards the impact of the project on nearby activities and downstream waters. These public apprehensions have been examined in depth by DER or its consultants.

Proposed methods of meeting these concerns will be noted in subsequent sections of the EIS.

In summary, the major items that trouble the public are:

1. Will there be degradation of downstream waters?
2. Will there be frost or freeze damage to citrus groves?
3. Will there be economic loss to commercial fishermen and fish camp operators?
4. Will there be adequate amounts of irrigation water available to farms and groves during the restoration?
5. What loss of fish and wildlife is anticipated?
6. How successful will the project be? Specifically,
   (a) Will the water quality be improved and remain so after restoration?
   (b) Would the water quality improve without a restoration project when all sources of pollution are abated?
7. What will the effect be on surrounding groundwater?
8. Will the project concentrate toxins and microbes*, and thus increase danger to humans and wildlife?

Clean Lakes

The Environmental Protection Agency (EPA) was authorized by Section 314 of the Federal Water Pollution Control Act (P.L. 92-500) to contract with appropriate public or private agencies, organizations, and individuals to provide funds for restoring and/or preserving lakes. This program is referred to as the Clean Lakes Program. EPA now accepts grant applications and, when appropriate, provides matching funds for lake restoration projects.

Table 1.2 summarizes the history of the Clean Lakes grant now in effect for a possible restoration of Lake Apopka. The Lake Apopka grant has remained the responsibility of DER since its June 1976 transfer from the Florida Game and Fresh Water Fish Commission.

Some of the funds from the Lake Apopka grant have been used for necessary studies preceding a restoration effort (hydrological, literature reviews, frost-freeze, and limnological). These studies are discussed elsewhere in this document. Additional funds would have to be made available for conducting a restoration effort and for pertinent post-restoration studies.

Table 1.2. History of the Clean Lakes Program Grant to DER for Lake Apopka Restoration Project.

DATE	EVENT
August 1972	DPC submits application to EPA for Lake Apopka grant.
June 1975	FG&FWFC submits application to EPA for Lake Apopka grant.
February 1976	EPA grant awarded to FG&FWFC.
June 1976	EPA grant transferred to Department of Environmental Regulation.

Project Objectives

The goals of a restoration of Lake Apopka are to halt and reverse the continuing degradation of the lake. Specific objectives are as follows:

1. Improve the water quality of Lake Apopka to meet state and local standards;
2. Provide aquatic habitats capable of supporting substantial game fish and wildlife populations;
3. Create lake conditions suitable for recreation and body contact;
4. Enhance the likelihood of water quality improvement in the Oklawaha chain of lakes by upgrading the water quality of Lake Apopka.

Successful restoration would mean reestablishment of a healthy gamefishery and a corresponding reduction in the proportion of rough fish. Increasing water clarity and consolidation and stabilization of bottom sediments would allow expansion of desirable rooted vegetation in the lake. This would correspond with a reduction in the lake's algal populations and a decrease in (or perhaps absence of) algal blooms. All of this would lead to greater recreational use of the lake and corresponding economic benefits to the surrounding area.

SECTION 2
EXISTING CONDITIONS

Meteorology and Climatology

Central Florida is a climatological transition zone between the more temperate northern section of the state and the more tropical zone to the south. The peninsular nature of Florida, with the Gulf of Mexico to the west and the Atlantic Ocean to the east, results in a substantial moderation of temperature. In addition, the abundance of lakes in Central Florida provides further buffering of temperatures. Though summers in the Lake Apopka area are long, warm, and humid, temperatures rarely exceed 35°C (95°F), and prevailing southeasterly winds aid comfort. Cold air masses with associated strong northwesterly winds regularly intrude into Central Florida during the winter months, but temperatures rarely drop below 0°C (32°F).

Figure 2.1 presents the yearly temperature pattern in Orlando, approximately 25 km southeast of Lake Apopka. These temperatures (maximum, mean, and minimum) are monthly averages compiled from 29 years (1941-70) of U.S. Weather Bureau records. The length of the warm season is immediately apparent with seven months (April-October) having average daily maximums over 27°C (80°F). It is noteworthy that no month has an average daily maximum in excess of 33°C (90°F). Only three months (December-February) have average daily minimums below 13°C (55°F), and the average daily maximums during these months are all over 22°C (70°F). Thus, the winter months are characterized by mild days and cool nights.

The highest temperature recorded during the 29-year period was 40°C (102°F), the lowest was -6°C (20°F). This is a range of only 46°C, much less than the yearly range expected in a more temperate climate. At their extremes, however, low temperatures have periodically caused substantial damage to Central Florida's valuable citrus and truck farming industries.

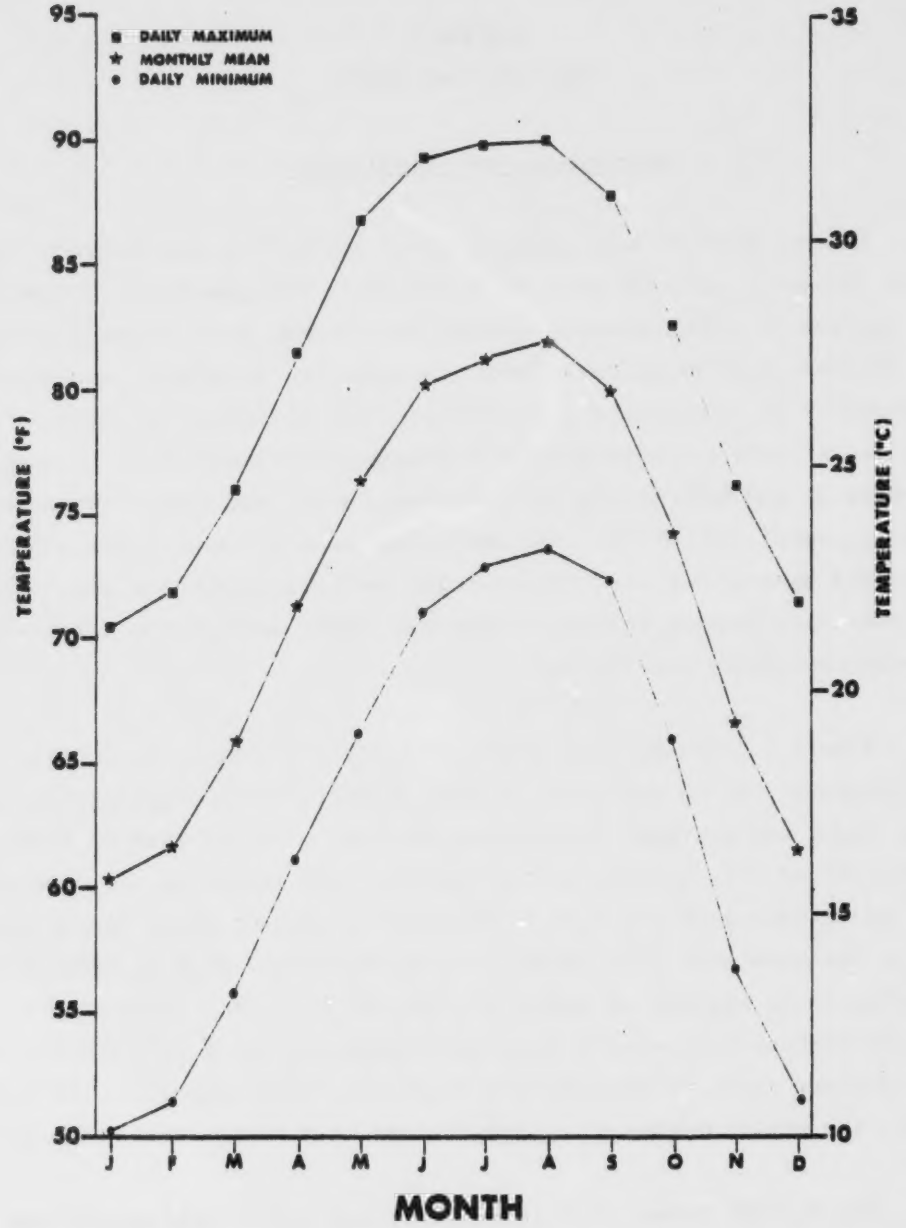

Figure 2.1. Yearly Temperature Pattern in Orlando, Florida. Data are means from U.S. Weather Bureau records, 1941-1970.

Rainfall data for Orlando are presented in Figures 2.2 and 2.3. These data are monthly averages compiled from 28 years (1934-1962) and 29 years (1931-1960) respectively, of data from U.S. Weather Bureau records. The average annual rainfall is 131 cm (52 in.) (Figure 2.2). Deviation from this average in most years was less than 25 cm (10 in.). An extreme drought occurred in 1938, while 1947, 1953, 1959, and 1960 were unusually wet years.

Figure 2.3 illustrates the pronounced rainy season, June through early October, when approximately 60 percent of the average annual rainfall occurs. During this period moisture-laden southeasterly winds prevail, and afternoon showers and thunderstorms occur on approximately 50 percent of the days. These storms are usually short, but can be intense, often dropping more than 5 cm (2 in.) of rain in less than 2 hours. The temperature falls sharply during these storms, often more than $5^{\circ}C$ ($10^{\circ}F$), thus providing greatly appreciated natural air-conditioning. Humidity remains quite high during the rainy season, rising to approximately 90 percent at night and remaining well above 50 percent in the afternoon.

Rainfall during the winter and spring is lighter and more irregular, and is usually associated with the passage of cold fronts. Extended dry periods occasionally occur in all seasons, but are more frequent in winter and spring. Agricultural operations lacking irrigation facilities can be seriously affected by these droughts.

A final topic of meteorological interest is that of hurricanes. Lake Apopka's location affords it some protection from these storms, for a hurricane would lose much of its energy passing over land before reaching the lake. However, hurricane-related winds in September 1947 did great damage to aquatic vegetation in the lake. In addition, rains from even a weakened hurricane can exceed 25 cm (10 in.) in less than two days.

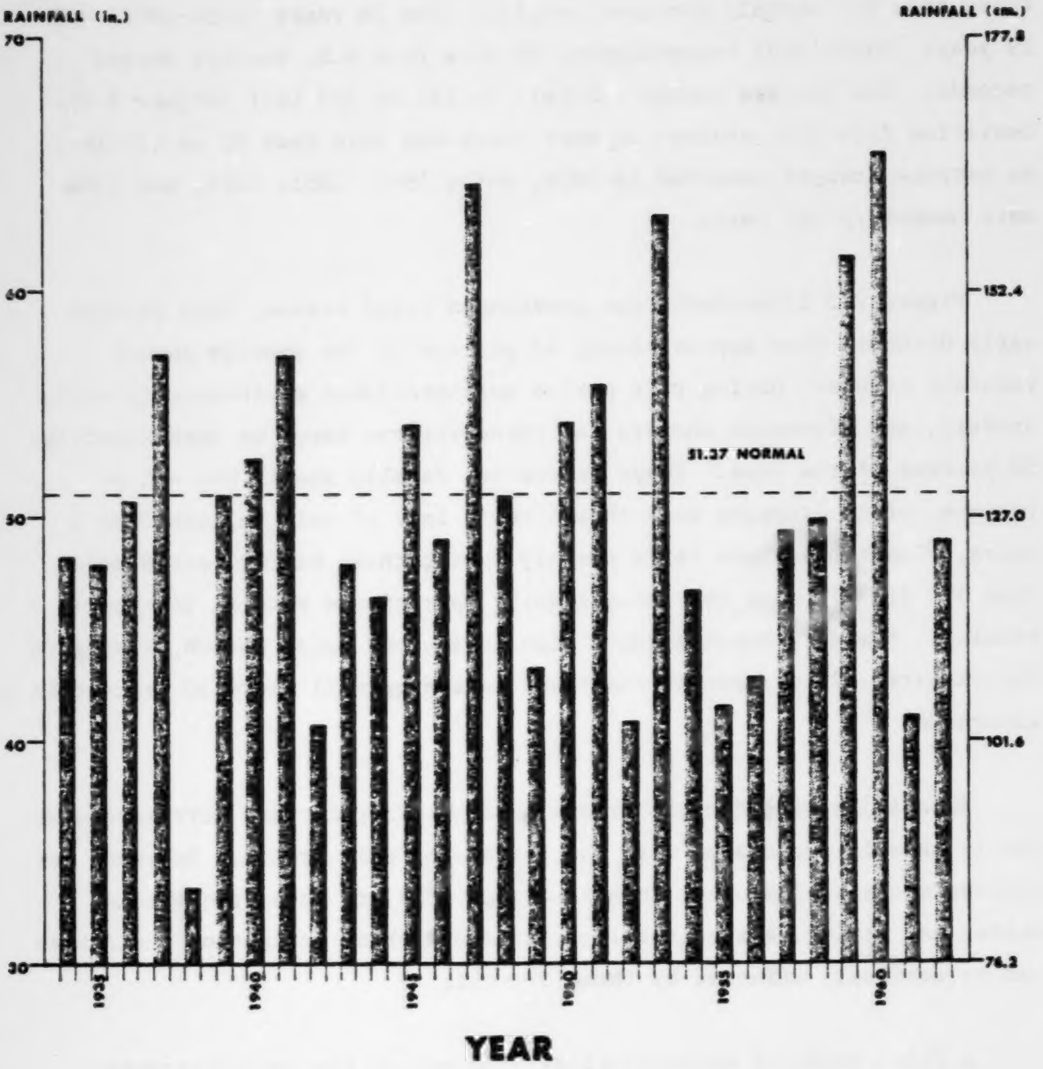

Figure 2.2. Annual Rainfall in Orlando, Florida. U.S. Weather Bureau Data, 1934-1962. The dotted line is the average for the 28-year period.

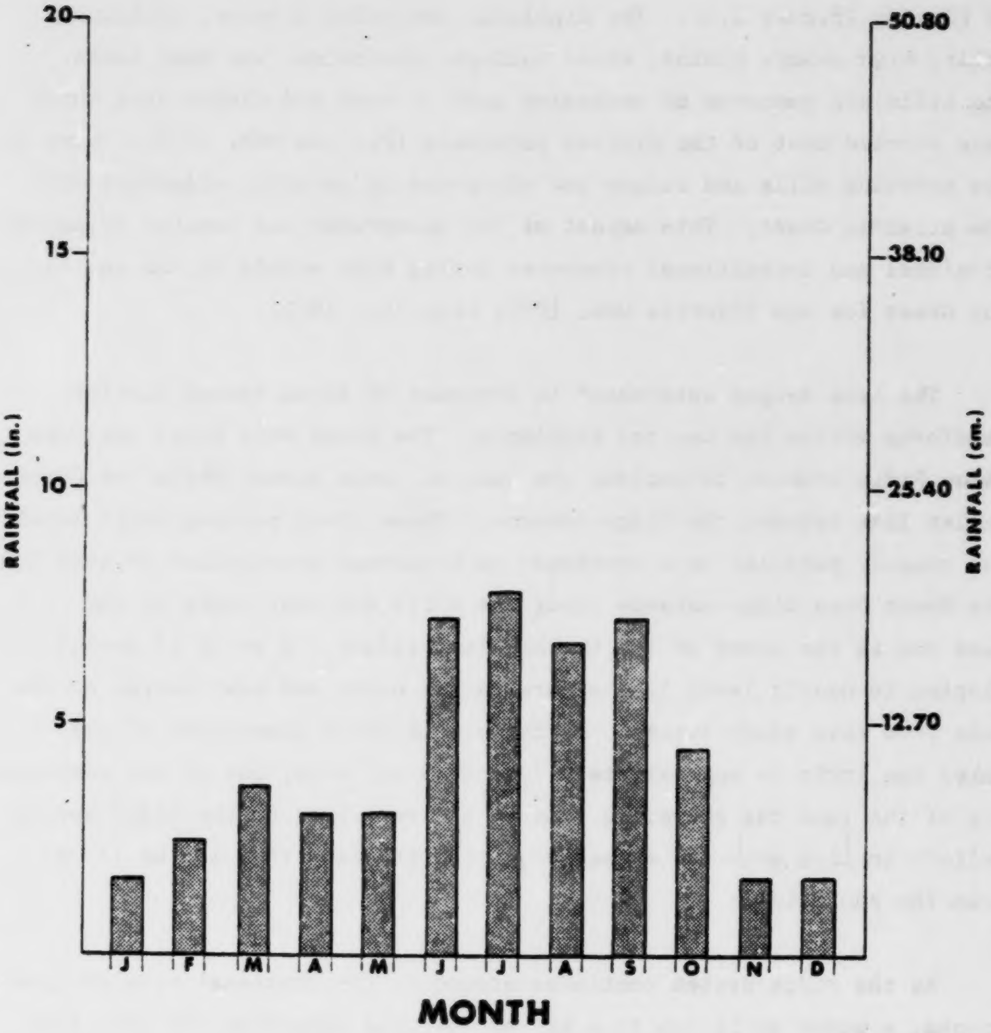

Figure 2.3. Average Monthly Rainfall in Orlando, Florida. U.S. Weather Bureau Data, 1931-1960.

Topography

Lake Apopka lies within the Central Highlands physiographic* division of Florida (Figure 2.4). The Highlands are quite diverse, containing hills, high swampy plains, river valleys, sinkholes, and many lakes. The hills are remnants of extensive beds of sand and clayey sand which once covered most of the Florida peninsula (Florida DNR, 1970). Many of the existing hills and ridges are elongated in parallel alignment with the Atlantic Coast. This aspect of the topography was created by marine erosional and depositional processes during high stands of the sea in the Great Ice Age (Florida DNR, 1970; Lichtler, 1972).

The Lake Apopka watershed* is composed of three rather distinct landforms within the Central Highlands. The Mount Dora Ridge and Lake Wales Ridge combine to enclose the lake on three sides, while the Central Valley lies between the ridge systems. These three physiographic landforms run roughly parallel in a northwest to southeast orientation (Figure 2.5). The Mount Dora Ridge extends along the north and east sides of the lake and is the lower of the two highland ridges. A strip of gently sloping to nearly level land separates the north and east shores of the lake from this ridge system. At its widest point (due north of the lake) the strip is approximately 7 km (2.5 mi) wide, but at the easternmost tip of the lake the shoreline lies at the very foot of the ridge system. Relief* in this area can exceed 30 m (100 ft) less than 1.6 km (1 mi) from the shoreline.

As the ridge system continues around to the southeast side of Lake Apopka, a wider strip (up to 4 km) of lowlands separates the lake from the highlands. At the southern edge of the lake near Winter Garden, the two ridge systems combine to form a U-shaped physiographic containment of the lake basin. Elevations in this section of the ridge system are lower and relief is less pronounced. From this point the Lake Wales Ridge extends to the northwest along the Lake Apopka shoreline. However, no continuous lowland area separates the lake from the highlands along this side of the lake (Figure 2.5).

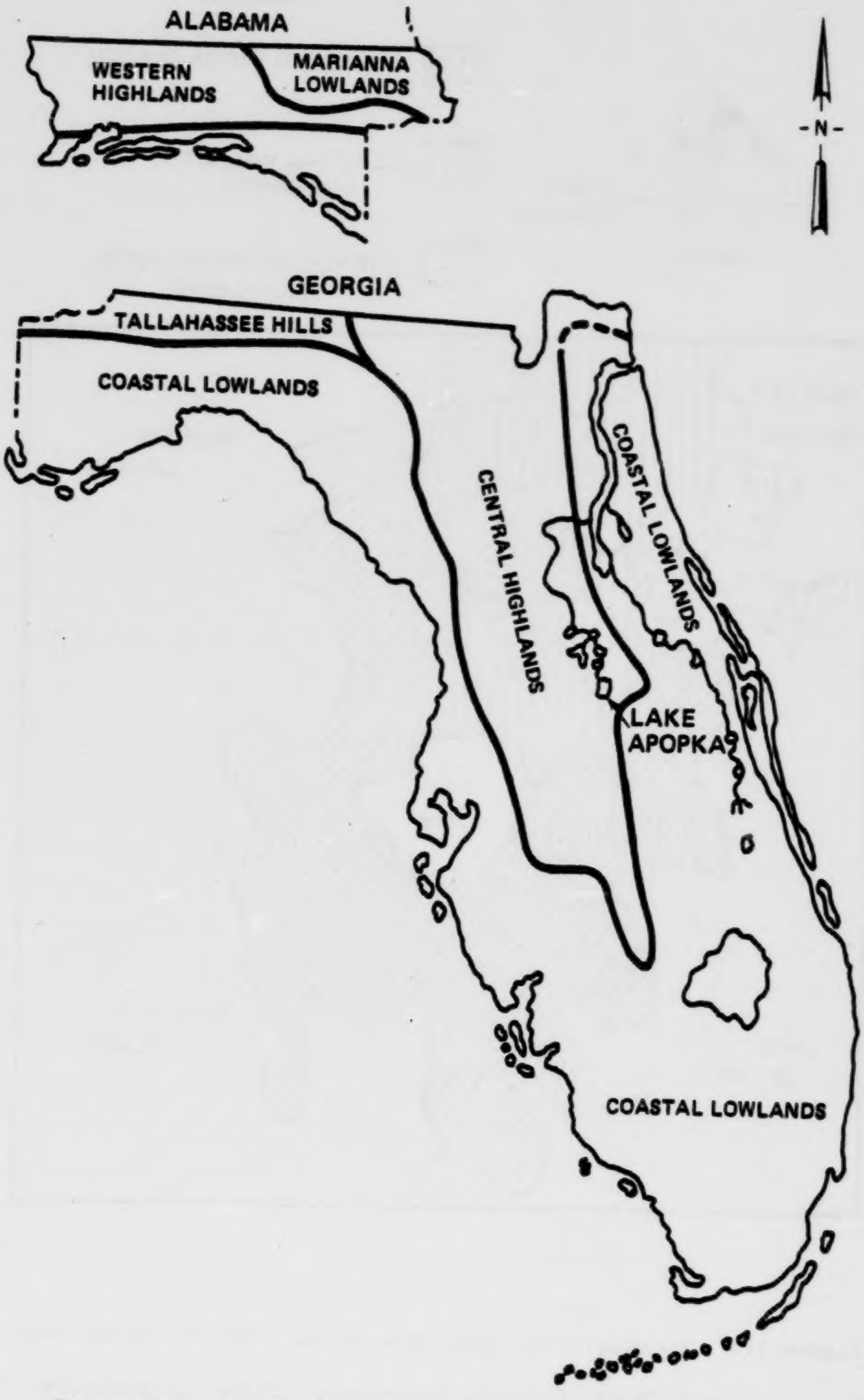
ALABAMA
WESTERN HIGHLANDS
MARIANNA LOWLANDS
N
GEORGIA
TALLAHASSEE HILLS
COASTAL LOWLANDS
CENTRAL HIGHLANDS
COASTAL LOWLANDS
LAKE APOPKA
COASTAL LOWLANDS

Figure 2.4. Major Physiographic Regions of Florida.

Source: Cooke, C.W., 1945. Geology of Florida
U.S.G.S. Bulletin No. 29.

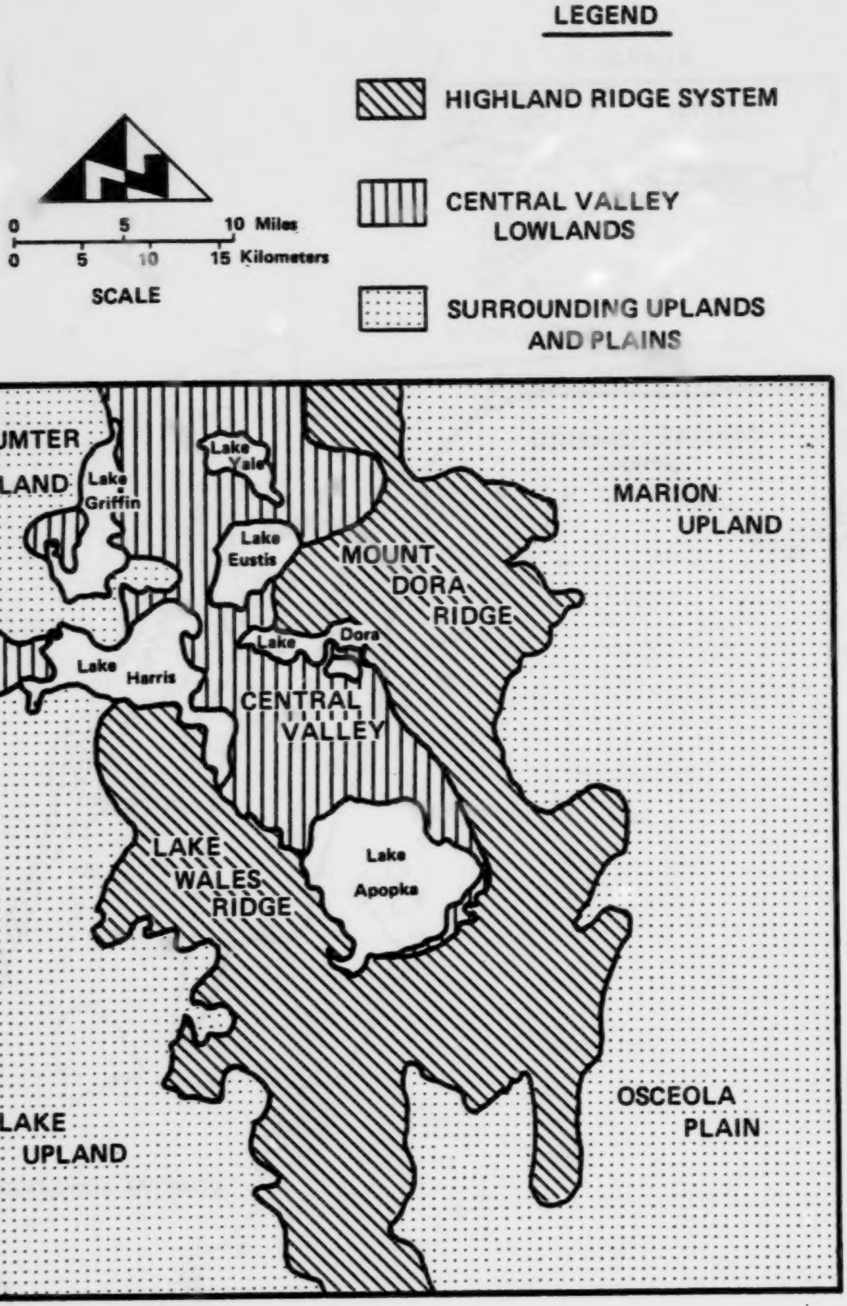
LEGEND
HIGHLAND RIDGE SYSTEM
CENTRAL VALLEY LOWLANDS
SURROUNDING UPLANDS AND PLAINS
0 5 10 Miles
0 5 10 15 Kilometers
SCALE
SUMTER UPLAND
Lake Griffin
Lake Yale
Lake Eustis
MARION UPLAND
MOUNT DORA RIDGE
Lake Dora
Lake Harris
CENTRAL VALLEY
LAKE WALES RIDGE
Lake Apopka
OSCEOLA PLAIN
LAKE UPLAND

Figure 2.5. Physiographic Landforms of the Oklawaha River Basin.

Sources: Lake County Planning Department, 1977. Conservation Element (Draft). Florida Department of Natural Resources, 1970. Water and Related Land Uses - St. Johns River Basin.

The Lake Wales Ridge, being the higher of the two ridges, contains hilltop elevations that can average from 60 to 90 m (200 to 300 ft) mean sea level (msl) (Lake County Planning Department (LCPD), 1977a). From Gourd Neck, along the west shore of Lake Apopka, past Montverde and up to the westernmost point of the lake, the shoreline is immediately adjacent to the Lake Wales Ridge. Sugarloaf Mountain, located at the western extremity of the lake, is 95 m (312 ft) above sea level and one of the highest points in peninsular Florida (LCPD, 1977a). From here the ridge system veers away from Lake Apopka and proceeds to the west of Little Lake Harris.

Within the highlands, drainage patterns are dendritic*, except where modified by man (Florida DNR, 1970). Elevations range from 15 m to over 90 m (50 to 300 ft) msl and can generate hillside slopes of up to 22 degrees (Lichtler, Anderson, and Joyner, 1968). These steeply sloping areas are totally within the sandy, highly permeable Lake Wales Ridge soils, however, and pose no serious erosional threat. Numerous karst* areas interlace the highlands and affect local drainage basins by closing them off from possible overland gravitational flow. This effect often results in small lakes which act as excellent groundwater* recharge conduits (Florida DNR, 1970).

The valley between the two ridges consists of flatter terrain and numerous large lakes. This area is known as the Central Valley and encompasses the entire Oklawaha Chain of Lakes (Apopka, Beauclair, Carlton, Dora, Harris, Eustis, Griffin, and Yale). Lake Apopka forms the southernmost extremity of this physiographic region, which extends to the northwest and opens into Lake County. The Central Valley topography varies from gently sloping terrain at the base of the ridge systems to extensive nearly level lowlands. Elevations range from 11 to 32 m (35 to 105 ft) msl, but most of the land lies between 15 and 26 m (50 and 85 ft) msl (Lichtler et al, 1968). The vast muck farm system along the north and northwest shores of Lake Apopka lies within the Central Valley and is typical of the terrain associated with this physiographic region.

This ridge and valley physiography also serves as a rough outline of the major drainage basin for Lake Apopka (Figure 2.6). Surface waters flow from this area in a northwest direction through the Chain of Lakes region and eventually into the Oklawaha River. The Palatlakaha River and Lake Apopka watersheds comprise the major drainage basin which forms the Oklawaha River. Although a narrow section of the Palatlakaha drainage sub-basin extends some 56 km (35 mi) south of Lake Apopka, the majority of the Lake Apopka sub-basin lies to the west and north of the lake. The highlands on either side of the Central Valley form a shallow, bowl-shaped landform which results in this northwest flow of water.

Geology

Geologic formations are directly responsible for the physiographic properties that an area exhibits. The sand ridges and interposing valley of the Lake Apopka region are no exception. This section of Central Florida was formed entirely through sedimentary processes over eons of prehistoric time (Florida DNR, 1970).

In early geologic times the Florida peninsula was part of a range of mountains which were subsequently worn down by erosion and subsided beneath the sea (Florida DNR, 1970). Sedimentary deposits consisting primarily of carbonates, gradually accumulated upon this shallow bank, while some sandy and clayey materials were transported by the sea and deposited in stratified layers. During the Pleistocene Epoch, the sea gradually withdrew until it reached its lowest historic level, then began to rise once more. As the sea continued to rise and rivers eroded the uplands, terrestrial deposits covered the stratified sediments.

These deposited materials underwent sedimentary processes and became the limestone, dolomite, sand, shale, and anhydrite that currently underlie Lake Apopka. Total thickness of these sedimentary formations is approximately 1830 m (6000 ft) (Scott, DNR, Bureau of Geology, personal communication). The five predominant geologic formations which form the top 460 m (1500 ft) of sediments are shown in Table 2.1 and are discussed below from oldest (deepest) to youngest.

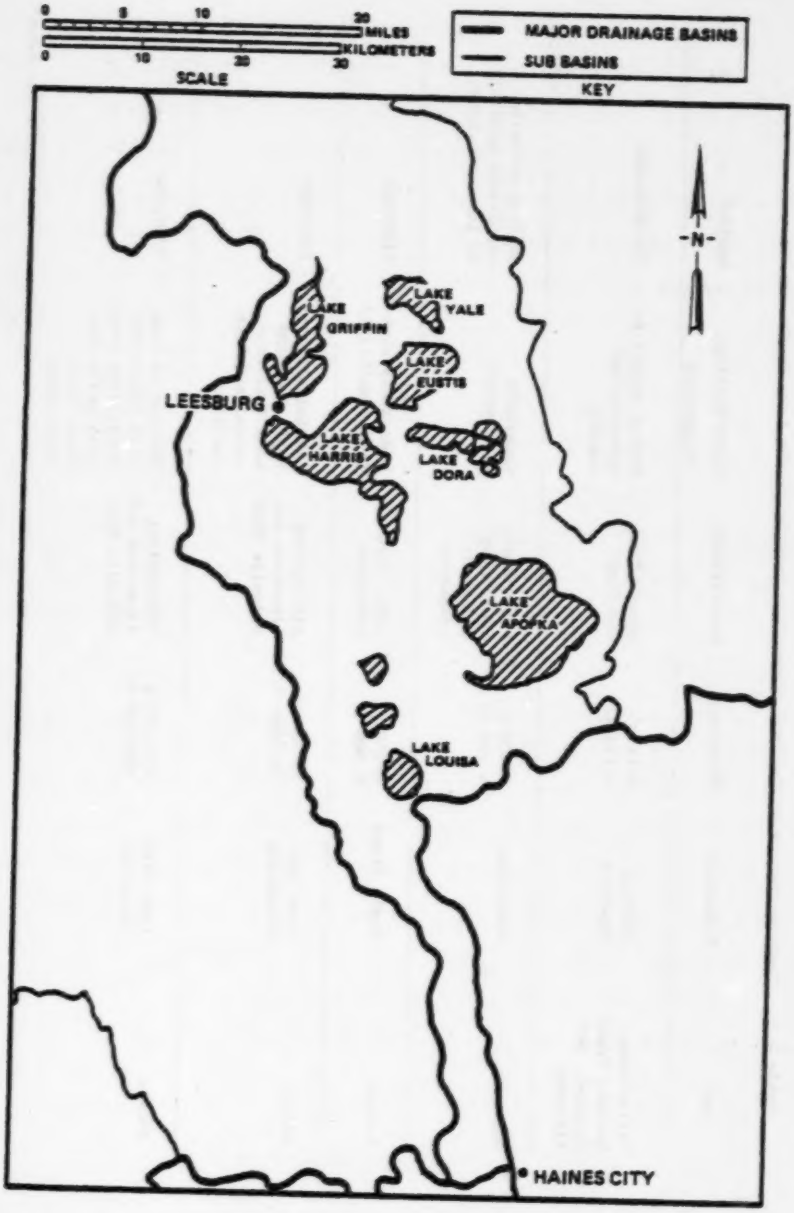
0
5
10
20
MILES
KILOMETERS
0
10
20
30
SCALE
MAJOR DRAINAGE BASINS
SUB BASINS
KEY
-N-
LAKE GRIFFIN
LAKE YALE
LAKE EUSTIS
LEESBURG
LAKE HARRIS
LAKE DORA
LAKE APOPKA
LAKE LOUISA
HAINES CITY

Figure 2.6. Upper Oklawaha River Drainage Basin.

Source: Hydrologic Unit Map - State of Florida, U.S. Geological Survey, 1974.

Table 2.1. Characteristics of Geologic Formations Underlying the Lake Apopka Region.

Age	Formation	Thickness	Description	Water-Bearing Properties	Aquifer
Pleistocene, Recent, Upper Miocene, and Pliocene	Surface Deposits	0-45 m 0-150 ft	Quartz Sand and Clay	Varies widely in quantity and quality	Non-artesian
Miocene	Hawthorne	0-150 m 0-500 ft	Clay, Sand, Sandy Clay, and Sandy Limestone	Generally impermeable	Shallow artesian conditions possible in limestone beds.
Eocene	Ocala Group	0-150 m 0-500 ft	Soft, Pure Limestone	Moderately high transmissibility	Floridan
Eocene	Avon Park Limestone	10-90+ m 30-300+ ft	Alternating Limestone and Dolomite Beds	Transmissibility high, contains many interconnected solution cavities	Floridan
Eocene	Lake City Limestone	120-150 m 400-500 ft	Alternating Limestone and Dolomite Beds	Similar to Avon Park Limestone. Many large capacity wells draw from these formations	Floridan

Source: Lichtler, W.F.; Anderson, W.; and Joyner, B.F., 1968. Water Resources of Orange County, Florida. U.S.G.S. R.I. No. 50.

The first layer is Lake City Limestone, which is about 50 million years old. It consists mainly of dolomite, limestone, and dolomitic limestone. The thickness of this formation averages about 120 to 150 m (400 to 500 ft) but ranges up to 200 m (700 ft). This formation is a main component of the Floridan Aquifer and yields large quantities of potable* water to many wells, often 20 to 40 m^3/min (5000 to 10,000 gpm) (Lichtler, 1972).

Directly above the Lake City Formation and conforming closely to it is the Avon Park Limestone. It consists of materials which are very similar to the Lake City Limestone, but is considerably thinner, averaging approximately 75 m (250 ft) (St. Johns River Water Management District (SJRWMD), 1977). This formation of the Floridan Aquifer is a principal source of potable water and has supported wells which pump upwards of 20 m^3/min (5000 gpm) (Lichtler, 1972).

The third major formation is the Ocala Group which, like the previous two formations, was formed during the Eocene Period. This formation is mainly composed of pure limestone which is soft, crumbly, and very porous. The group is generally divided into three formations--the Crystal River Formation, the Williston Formation, and the Inglis Formation. These formations were formed from relatively pure carbonates, and provide moderate to large amounts of water. In fact, almost all deep water wells that extract water from the Floridan Aquifer do so in part from the Ocala Group Limestone (SJRWMD, 1977). This water is usually potable.

The Hawthorn Formation, which is roughly 25 million years old, overlies the Ocala Group. Clay, quartz sand, clayey sand, sandy limestone, and phosphatic materials are the main constituents of this formation. These materials are relatively impermeable compared to the Eocene limestone. Clayey sand is the most important component because it retards vertical movement of water between the water table* aquifer* and the underlying limestone of the Floridan Aquifer (ECFRPC, 1978). This separation of the two aquifers plays an important role in the hydrology of the area. Beds of limestone within the Hawthorn formation sometimes yield medium to large quantities of water to wells, but generally the formation acts as an aquiclude* (Lichtler et al, 1968).

Undifferentiated sediments consisting mostly of loose, unsorted quartz sand, clay, and some organic matter overlie the Hawthorn Formation. Much of the sand in these sediments was deposited during the Pleistocene Ice Age as marine terraces and can reach substantial depths in the higher elevations of the Lake Dora and Lake Wales Ridge systems. In some places sand can reach depths of 45 m (150 ft), thereby acting as an excellent groundwater recharge source (SJRWMD, 1977).

A more simplistic approach to geologic analysis of this area is through an examination of three major components: 1) the Clastic Aquifer, 2) the Hawthorn Formation, and 3) the Floridan Aquifer. The Clastic Aquifer, or non-artesian* aquifer, extends from a depth of 5 m (15 ft) to a maximum of 60 m (200 ft). Beneath this lies the 30 m (100 ft) thick Hawthorn Formation, which acts as the confining layer for the artesian* or Floridan Aquifer. The Floridan Aquifer contains layers of limestone up to 300 m (1000 ft) thick (LCPD, 1977a).

The Clastic Aquifer contains highly permeable sandy materials which act as a filter bed to purify gravity-fed groundwater. Since the Hawthorn Formation retards vertical water movement, water that infiltrates from the land surface is stored in the Clastic Aquifer. When local conditions are favorable, some of this water eventually recharges the Floridan Aquifer. Where the water table is flat, such as in the highly permeable upland areas, most water infiltrates downward to eventually recharge the Floridan Aquifer. Where the water table slopes significantly, groundwater has a greater probability of leaving the Clastic Aquifer by discharging into a stream or spring (LCPD, 1977a). This results in less groundwater for recharge of the artesian aquifer.

The Floridan Aquifer is the predominant source of water in the Lake Apopka area. Nearly 85 percent of the water utilized for industry, agriculture, municipal, and domestic uses in this area originates from the Floridan Aquifer (LCPD, 1977a). Because of artesian pressure and the high permeability of the aquifer formations, it is not uncommon for wells drawing from this source to pump more than 20 m^3/min (5000 gpm) (Lichtler et al, 1968). Average depth below land surface to the top of the Floridan Aquifer is approximately 30 to 45 m (100 to 150 ft) in the Lake Apopka area.

Groundwater can move between the two aquifers if certain physical conditions exist. Most importantly, there must be a conduit or permeable area in the Hawthorn Formation which will permit the movement of water. There must also be a difference in pressures between the aquifers. If the downward force of gravity in the nonartesian aquifer is greater than upward pressure in the Floridan Aquifer, water will be forced down into the Floridan Aquifer. If the opposite situation exists, water will be discharged from the Floridan Aquifer upward into the Clastic Aquifer. In the area surrounding Lake Apopka the former of these two circumstances usually prevails.

Soils

The geologic structure of an area influences not only physiographic features, but also soil types. Dominant soil associations* are dependent on geologic formations which lie close to the surface, because it is from these materials that soils are derived. Soils are also strongly affected by slope, relief, and properties of geologic formations such as porosity* and permeability*. Hence, there is a direct relationship between geology, topography, and soil composition.

Soils in the Lake Apopka region range from the excessively-drained, very sandy soils of the highland ridges to the very poorly-drained muck soils north of the lake. Figure 2.7 illustrates the approximate spatial distribution of major soil associations around the lake, while the following text describes the characteristics of each of these associations.

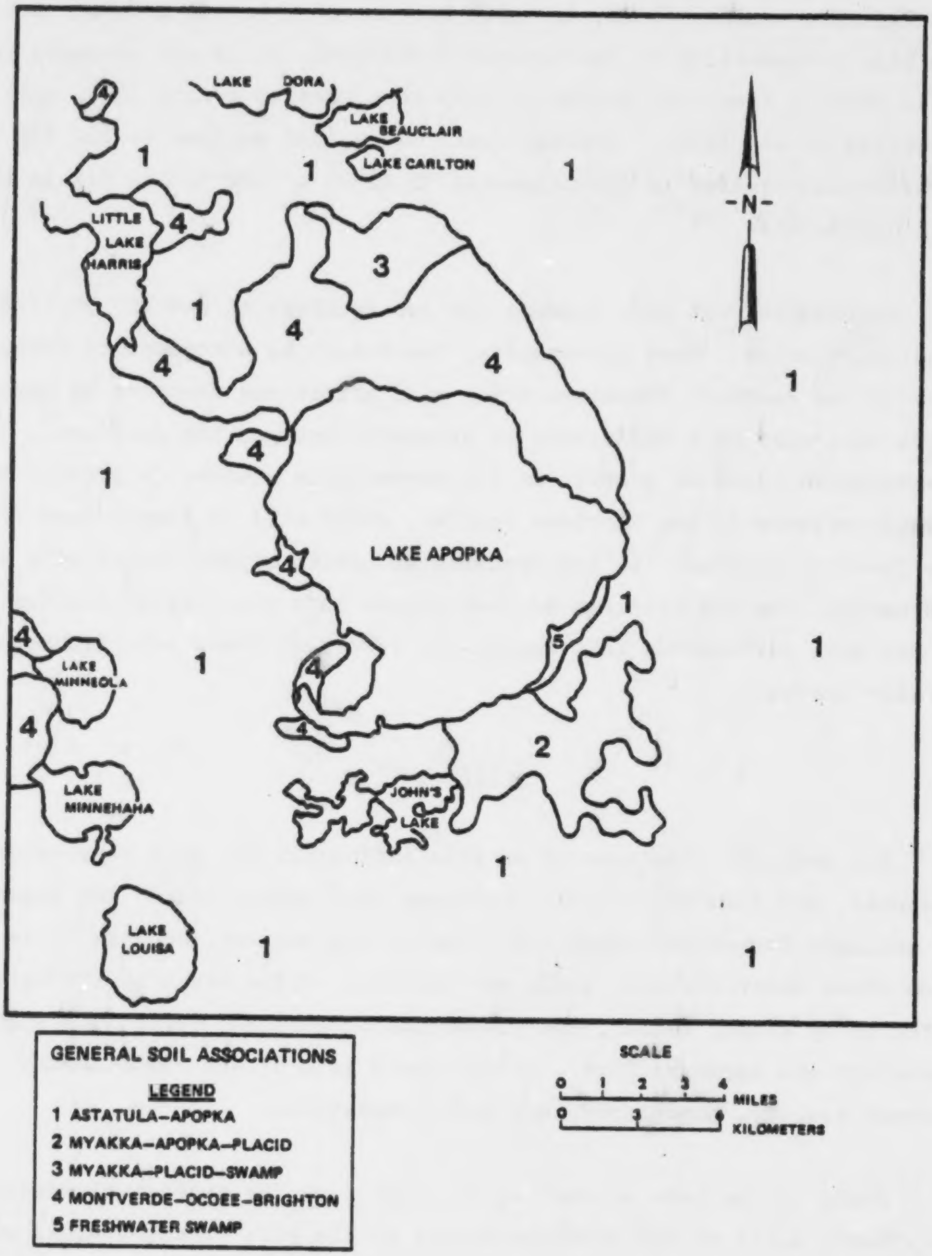
LAKE DORA
LAKE BEAUCLAIR
LAKE CARLTON
LITTLE LAKE HARRIS
LAKE APOPKA
LAKE MINNEOLA
LAKE MINNEHAHA
JOHN'S LAKE
LAKE LOUISA
-N-
1
2
3
4
5
GENERAL SOIL ASSOCIATIONS
LEGEND
1 ASTATULA–APOPKA
2 MYAKKA–APOPKA–PLACID
3 MYAKKA–PLACID–SWAMP
4 MONTVERDE–OCOEE–BRIGHTON
5 FRESHWATER SWAMP
SCALE
0 1 2 3 4 MILES
0 3 6 KILOMETERS

Figure 2.7. General Soil Associations.

Source: Florida General Soils Atlas, Districts V and VI, 1975.

Astatula-Apopka soils comprise the majority of land around Lake Apopka. These soils are associated almost exclusively with the highland ridges in the area and are sandy throughout. They are well-drained to excessively-drained, strongly acidic, very porous soils which are low in organic matter and fertility (LCPD, 1977a). Because this association is so porous and permeable, ridges composed of this soil do not support many streams and erosion is negligible. Similarly, water-holding capacity of the soils is low, and the water table may be as much as 300 cm (120 in.) below the surface (Leighty et al, 1960). These characteristics combine to allow an average annual recharge of the Floridan Aquifer of 15 to 25 cm (6 to 10 in.) in the highland ridge areas (LCPD, 1977a).

Sands of the Astatula-Apopka Association can reach depths of 200 cm (80 in.). Although these thick sandy beds are low in natural fertility, citrus groves planted in this soil produce good yields. Irrigation is desirable and although the soil is droughty during long dry seasons, it responds well to proper fertilizing and liming (Furman et al, 1975). Most of the Astatula-Apopka soils in the Lake Apopka region have been planted in citrus.

Southeast of Lake Apopka near Winter Garden and Ocoee, an irregularly-shaped area of Myakka-Apopka-Placid soils exists. This association varies only slightly from the Astatula-Apopka Association and corresponds to the lower elevations of this section of the highlands ridge system. Like the Astatula-Apopka Association, these soils were formed from thick deposits of marine sands, but are not as permeable or porous. Consequently, the association ranges from moderately-well to poorly-drained soils, and water table levels fluctuate substantially (Leighty et al, 1960). These soils are not as well-suited to citrus production as Astatula-Apopka soils; however, citrus crops are cultivated in this area. In order to maximize yields from these crops, intensive management and artificial drainage are necessary.

Northeast of Winter Garden and immediately adjacent to the lake is a narrow strip of Freshwater Swamp soils. These soils are nearly level, very poorly-drained and subject to prolonged flooding (Bureau of Comprehensive Planning, 1975). This four-mile stretch of the lake shore is lightly developed but supports a dense growth of water-tolerant vegetation.

Along the entire northern section of Lake Apopka, soils belong to the Montverde-Ocoee-Brighton Association. This association comprises the muck soils farm area and surrounding lowlands. Muck soils were formed under wet, poorly-aerated conditions and have accumulated significant amounts of organic material which may attain depths of 130 to 200 cm (50 to 80 in.) or more (Furman et al, 1975). Muck soils are very poorly-drained, and little downward percolation of groundwater occurs. Average annual recharge to the Floridan Aquifer in this region, therefore, is limited to 5 cm (2 in.) (LCPD, 1977a).

Muck soils have a high natural fertility and contain large amounts of nitrogen, but are deficient in other essential plant nutrients. The water table is at the surface and water capacity is high; therefore, drainage is often necessary before these soils can be planted in vegetables and field crops. When the soil is not supporting a crop, the water table must be maintained at a high level or subsidence of the organic matter will occur. This subsidence is related to oxidation* and can substantially reduce the agricultural potential of the soil. Average annual subsidence rates of 1.40 cm and 4.83 cm have been positively correlated to water table depths of 30 cm and 91 cm respectively (Neller, 1944). Small sections of Montverde-Ocoee-Brighton soils also occur along the western shores of the lake, but these areas are presently not developed as agricultural lands.

Farther north from these muck soils lies an area of Myakka-Placid-Swamp soils. These soils are also poorly drained and subject to prolonged flooding, but are sandy in composition. The water table fluctuates from shallow to deep, but, unlike the muck soils, Myakka-Placid-Swamp soils have a low moisture-holding capacity. Although these soils are an extension of the muck soils, they are low in organic matter and natural fertility and usually experience medium rates of internal drainage (Leighty et al, 1960). As a result, Myakka-Placid-Swamp soils are not as productive as muck soils, but if managed properly can supply fair yields of field crops and vegetables. Unlike the muck soils, if the Myakka-Placid-Swamp soils are drained they can furnish medium to high yields of citrus crops.

The soils of the Lake Apopka area are directly related to topography. Sandy well-drained soils with deep water tables are located along the highland ridges. Southeast of Lake Apopka, where elevations drop off, the soils become less well-drained, yet remain sandy in composition. Around the entire northern section of the lake, poorly-drained organic and semi-organic soils are associated with the Central Valley region. These soils have shallow water tables and are more conducive to vegetable farming than residential development or citrus production.

Hydrology

Hydrology is the science dealing with the distribution and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere. The description of hydrology given in this section relies heavily upon information presented in the four preceding sections: Meteorology and Climatology, Topography, Geology, and Soils.

Bottom Characteristics

The Lake Apopka bottom is composed of peat, sand, limestone outcroppings and muck. In some locations the organic deposits (peat and muck) have been found to exceed a thickness of 16 m (53 ft). While 90 percent of the lake bottom is covered with organic deposits, some thin, near-shore bands of sand are occasionally exposed by the movement of the fluid-like muck.

As pointed out in the Geology Section, recharge to the Floridan Aquifer does take place in the Apopka area; however, the clay and sandy clay material under Lake Apopka prevent recharge of the aquifer through the lake bottom itself. Apopka Springs, in the Gourd Neck region of the lake, with a flow of about 0.76 m^3/sec (26.8 ft^3/sec) is a notable exception to the general retardation of water exchange caused by the layer of impermeable materials in the lake bottom.

Water Quantity

Lake Apopka has a surface area of about 12,500 hectares (31,000 acres), an average surface elevation of 20.4 m mean sea level (66.9 ft msl), and an average depth of 1.5 m (5 ft). Forty percent of the lake is less than 1.2 m (4 ft) deep while only 4 percent is greater than 2.4 m (8 ft) deep. The lake holds 182.1 million m^3 (54 billion gal) of water (not including water in the muck and peat layers).

Water Budget

The net water input to Lake Apopka (not including that lost to evaporation, irrigation or seepage) is easily calculated by the formula:

Net Input = Water Outflow through Apopka-Beauclair Canal Plus Increase in the Amount of Water Stored in the Lake.

The net input, of course, is quite variable from month to month depending upon season (Table 2.2). In the 18-year period (1959-1976) the mean monthly net input ranged from a net water loss of 6.34 million m^3 (5140 acre-ft) in April, to a net gain of 18.66 million m^3 (15,120 acre-ft) in August.

Over this 18-year period the net input also varied with the year, ranging from a net water loss of 8.13 million m^3 (6590 acre-feet) for 1974, a dry year, to a net gain of 228.8 million m^3 (185,470 acre-ft) in 1960, a wet year (Table 2.3). The mean annual net input over the 18-year period was 79.56 million m^3 (64,490 acre-ft).

Attempts have been made to itemize Lake Apopka's water budget into its 1) sources of water and 2) losses of water. Quantifying this type of budget is difficult due to lack of data and the interdependency of the quantity of some items upon the quantity of others.

A. Sources. Direct rainfall makes up about 48 percent of the input in Lake Apopka's water budget. Input of 164.3 million m^3 per year

Table 2.2. Mean Monthly Net Input to Lake Apopka Between 1959 and 1976. Net Input = Water Outflow through Apopka-Beauclair Canal Minus Change in Amount of Water Stored in Lake.

Month	Cubic Meters (in millions)	Acre-Feet (in thousands)
January	9.76	7.91
February	11.99	9.72
March	10.18	8.25
April	-6.34	-5.14
May	-6.13	-4.97
June	8.15	6.61
July	9.62	7.80
August	18.66	15.12
September	17.83	14.46
October	-1.06	-0.86
November	2.73	2.22
December	4.16	3.37

Source: Anderson, W., 1977. Addendum to Hydrologic Considerations in Draining Lake Apopka: A Preliminary Analysis. U.S. Geological Survey.

Table 2.3. Yearly Net Input to Lake Apopka. Net Input = Water Outflow through Apopka-Beauclair Canal Minus Change in Amount of Water Stored in Lake.

Year	Cubic Meters (in millions)	Acre-Feet (in thousands)
1959	191.05	154.87
1960	228.80	185.47
1961	23.92	19.39
1962	8.28	6.71
1963	74.78	60.62
1964	82.36	66.76
1965	39.81	32.27
1966	77.06	62.47
1967	38.62	31.31
1968	120.12	97.37
1969	139.25	112.88
1970	106.81	86.58
1971	75.63	61.31
1972	49.57	40.18
1973	47.28	38.33
1974	-8.13	-6.59
1975	82.58	66.94
1976	54.24	43.97
Mean of the 18 years	79.56	64.49

Source: Anderson, W., 1977. Addendum to Hydrologic Considerations in Draining Lake Apopka: A Preliminary Analysis. U.S. Geological Survey.

(184 cfs) attributed to rainfall is based upon an average annual rainfall of 131.3 cm (51.7 in.) (Anderson, 1970).

Depending upon the seasonal rainfall, the muck farms to the north either use water from the lake or supply water to the lake. The muck farms are low-lying land masses which receive water as surface drainage and ground water from the surrounding high areas, gravity drainage from Lake Apopka, and rainfall. During the wet season considerable amounts of water must be pumped off the farms to maintain the desired 45.7 cm (18 in.) water table. Pumpage from the muck farms to Lake Apopka was estimated to be 142.9 million m^3 per year (160 cfs) between 1964 and 1968 (Anderson, 1970). The construction of recycling ponds for the containment of farm water pumpage as a part of the nutrient abatement program is reducing the muck farms' contribution of water to the lakes. Those farmers outside Zellwood District #2 have already decreased their pumpage by 50 percent.

Flow from Apopka Springs varies with the water level of Lake Apopka. As the water level of the lake decreases, the weight of water over the springs also decreases, thus reducing the pressure which is holding back the upward flow of water. Consequently, a reduction of water level in Lake Apopka results in an increased flow from the springs. Anderson (1977) stated that "flow from Apopka Springs is 3.27 cfs for each foot of difference in the water levels in Gourd Neck Well and Lake Apopka." Between 1960 and 1976 Apopka Springs' flow averaged 23.8 million m^3 per year (26.7 cfs).

Effluents from the Winter Garden Sewage Treatment Plant equalled 1.1 million m^3 for the period 4/76 to 4/77 (1.2 cfs, Anderson, 1977). With the completion of new treatment facilities scheduled for 1979, this effluent will be completely eliminated.

Effluent from the Winter Garden Citrus Cooperative equalled 5.5 million m^3 for the period 4/76 to 4/77 (6.1 cfs, Anderson, 1977). After the construction of percolation ponds and spray fields, this flow was reduced to 3.4 million m^3 for the period 4/77 to 4/78 (3.9 cfs).

Occasional overflow from John's Lake and seepage from the water table aquifer also contribute to Lake Apopka's water budget. The quantity contributed by John's Lake has not been measured but is considered insignificant. The water table aquifer contribution is estimated to be about 1.3 million m^3 per year (1.5 cfs, Anderson, 1970).

B. Losses. Evaporation accounts for an estimated 45 percent of the output in Lake Apopka's water budget. The evaporation rate, 151.7 million m^3 per year (170 cfs), is based on an average evaporation rate of 121.2 cm (47.7 in.) per year (Anderson, 1970).

The next highest output in the water budget is gravity drainage to the muck farms. Using water budget values given above and assuming that recharge of the aquifer from the lake bottom is insignificant, Anderson's (1970) formula indicates that drainage to the muck farms is about 103 million m^3 per year (115 cfs).

Outflow through the Apopka-Beauclair Canal, based on the annual average for the period 1959-1968 equals 83.9 million m^3 per year (94 cfs) (Anderson, 1970).

Recharge of the aquifer through the lake bottom is retarded by the sandy clay material under Lake Apopka. As a result, water loss through the bottom is considered insignificant.

Forty percent of the citrus groves surrounding Lake Apopka use the lake's water for irrigation (Ramsey, RSB&W, personal communication). No data have been collected concerning the quantity of water used in citrus irrigation, but such use is considered insignificant.

Flood Hazards

As seen in Figure 2.8, water flowing out of Lake Apopka must pass through a series of five channels before reaching the main body of the Oklawaha River. These channels are the Apopka-Beauclair Canal, Beauclair-Dora Canal, Dora Canal, Haines Creek and the channelized portion of the upper Oklawaha River.

A. Apopka-Beauclair Canal. The surface elevation of Lake Apopka is maintained between 20.3 and 20.6 m (66.5-67.5 ft) msl. This is accomplished by means of a water control structure located in the Apopka-Beauclair Canal. The canal has a maximum daily discharge of 21.3 m^3/sec (754 ft^3/sec) but an average daily discharge of only 12.5 percent of this maximum.

B. Dora Canal. This canal is an environmentally sensitive area. It is surrounded by a cypress swamp which serves as a nesting area for various bird species. Secondary canals branching from the Dora Canal provide low-lying waterfront lots for residential homes behind the swamp.

The Dora Canal receives water from Lakes Dora, Beauclair, Carlton and Apopka, and yet, its maximum daily discharge is only 55.7 percent of that of the Apopka-Beauclair Canal. At its average flow, the Dora Canal operates at 30.9 percent of its capacity and carries 1.4 times the amount of water that is carried by the Apopka-Beauclair Canal.

C. Haines Creek. In addition to the waters upstream of the Dora Canal, Haines Creek receives water from Lake Harris (via the Dead River) and from Lake Eustis. As a result, Haines Creek normally carries slightly more than three times the water of the Apopka-Beauclair Canal. Water flow in Haines Creek is controlled by the Burrell Control and Lock.

D. Moss Bluff Dikes. The channelized upper Oklawaha River, at the Moss Bluff Dikes, carries water from Lakes Griffin and Yale and all the lakes upstream of Haines Creek. Under normal conditions, this is almost four times the amount of water carried by the Apopka-Beauclair Canal. The Moss Bluff Control and Lock regulates the flow of the upper Oklawaha River while aiding in the management of the upstream lake elevations.

Summary of Flood Hazards

Flow rate through a channel is partially determined by the difference in elevation of the bodies of water at each end of the channel. The greater the difference, the greater the flow. Thus, when there is an overabundance of water flowing between two lakes the channel may be

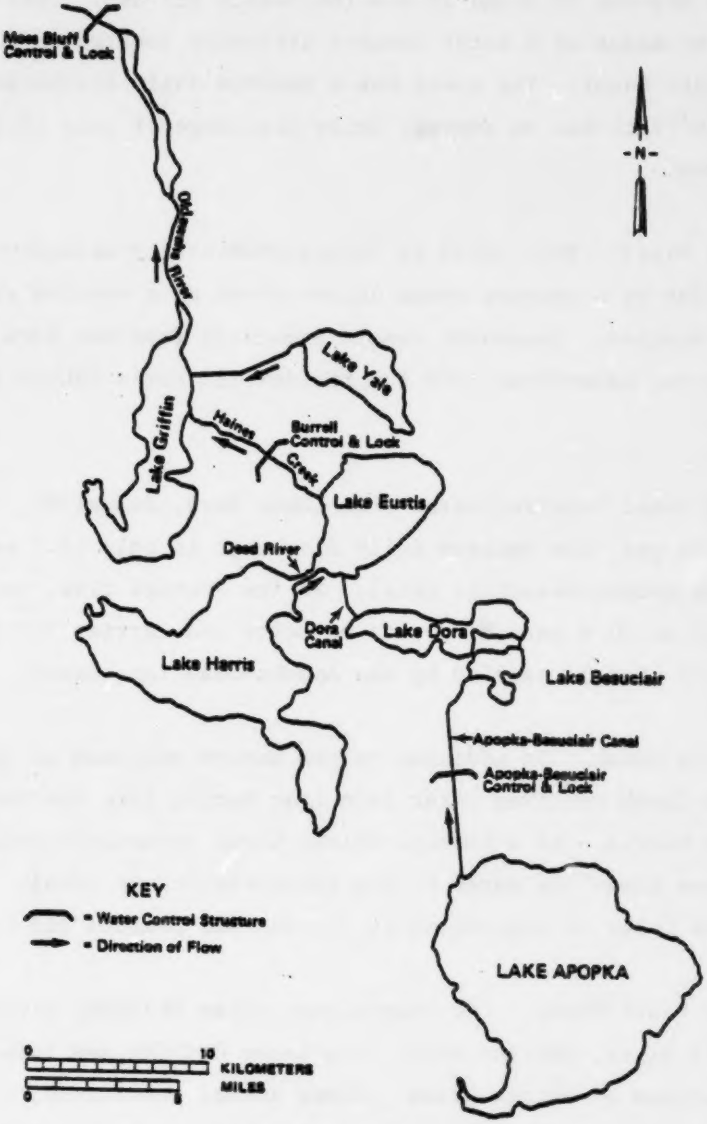
Moss Bluff Control & Lock
N
Oklawaha River
Lake Yale
Lake Griffin
Haines Creek
Burrell Control & Lock
Lake Eustis
Dead River
Dora Canal
Lake Dora
Lake Harris
Lake Beauclair
Apopka-Beauclair Canal
Apopka-Beauclair Control & Lock
KEY
= Water Control Structure
= Direction of Flow
LAKE APOPKA
0
10
KILOMETERS
MILES
0
5

Figure 2.8. Oklawaha Chain of Lakes and Water Control Structures.

thought of as a bottleneck. When the flow exceeds the capacity of the channel, flooding of the upstream lake results. Table 2.4 presents the average and maximum flows of the four major channels and the percent of the maximum daily discharge represented by the average flow.

Each channel receives water from its own lake source as well as water from all other upstream lakes. Therefore, the average flow rate increases for each succeeding downstream channel. Note that while the average flow rate does increase for each succeeding downstream channel, the maximum daily discharge does not. As a result, if the flow rate of all channels is increased proportionally due to a heavy rain, some downstream channels will reach capacity before upstream channels if control measures are not taken.

Table 2.4. Discharge Rates along the Oklawaha Chain.

	Avg. m^3/sec	Max. m^3/sec	% of maximum daily discharge represented by the average flow
Apopka-Beauclair Canal	2.6	21.3	12.5
Dora Canal	3.6	11.8	30.9
Haines Creek	8.1	36.8	22.2
Moss Bluff	10.4	45.3	23.1

Source: DPC, 1972. Lake Apopka Restoration Project; Project Plan.

There are three water control structures on the Oklawaha Chain of Lakes: the Apopka-Beauclair Control and Lock, the Burrell Control and Lock, and the Moss Bluff Control and Lock. By manipulating the water flow through these three control structures the water levels of the Oklawaha Chain of Lakes are regulated within a relatively narrow range. Table 2.5 presents the desirable levels for the Oklawaha chain as established by the Southwest Florida Water Management District (SWFWMD) and currently regulated by the St. Johns River Water Management District (SJRWMD).

Due to its limited flow capacity and the low retaining wall, where one exists, the Dora Canal is the limiting channel in the system. If flooding were to occur due to natural causes, it would appear that the Dora Canal and lakes upstream of it would be the affected locations. However, conversations with representatives of SJRWMD and FG&FWFC and with residents along the Dora Canal indicate flooding has been well controlled.

In 1967 a SWFWMD report considered new regulatory stages for the Oklawaha Chain of Lakes which would have created a new category of levels called the maximum operating level (MOL). The proposed MOL is equal to the current maximum desirable level (MDL) except for Lakes Apopka and Yale, where the MOL is 0.15 m (0.5 ft) greater than the MDL. In regard to flood hazards with the MOL, the report states, "Inconvenience to lake residents, with the exception of some docks being flooded as a result of high water is.....not great......All MOL's are at least 0.46 m (1.5 ft) below the lowest floor slabs found. A few scattered seawalls will experience some over-topping with heavy wind-driven waves, a condition that occurs even with the present operating schedule," (SJRWMD, 1976).

Table 2.5. Minimum and Maximum Legal Desirable Lake Levels for the Oklawaha Chain of Lakes.

Lake	Surface Elevation Above Mean Sea Level (in meters)[1]	
	Minimum	Maximum
Apopka	20.3	20.6
Beauclair	18.9	19.5
Dora	18.9	19.5
Harris	18.9	19.4
Eustis	18.9	19.4
Griffin	17.7	18.1
Yale	17.8	18.4

[1] Conversion factor: meters multiplied by 3.281 equal feet.

Source: SJRWMD, 1976. Report of the Streamflow and Fluctuation of the Okalwaha River and Oklawaha Chain of Lakes.

Water Quality

The surface waters of the Upper Oklawaha River Basin are designated Class III waters, a category of waters which, if standards were being met, would be suitable for recreational uses and for fish and wildlife propagation and management. Lake County and Orange County have further classified the Apopka Chain as Class III A, waters to be used for body contact recreation. Local pollution control ordinances prohibit inadequately treated industrial or domestic waste discharges into Class III A waters; however, variances have been granted to existing wastewater sources to allow continued discharge during the upgrading of their facilities.

In 1973, the East Central Florida Regional Planning Council (ECFRPC) compared water quality in the various lakes of the Upper Oklawaha River Basin and identified trends of nutrient increases in several lakes. The report concluded that Lakes Apopka, Beauclair, Carlton, and Dora exhibited the most severe water quality problems in the basin, and that the transport of water from Lake Apopka to downstream lakes had contributed to the water quality problems in those lakes (DER, 1977).

A later nutrient loading analysis of Lake Griffin, the last lake in the Apopka Chain, clearly substantiated this point. The nutrient loading rates developed for Lake Griffin during the National Eutrophication Survey in 1975 showed that 80.4 percent of the annual nitrogen loading and 67.6 percent of the annual phosphorus loading to Lake Griffin were contributed by Haines Creek and thus from upstream sources (DER, 1977).

ECFRPC also identified Lakes Apopka, Beauclair, Carlton, Dora, Eustis, and Griffin as having periodic algal blooms, while Lakes Yale and Harris were noted to have better water quality, more representative of natural conditions (DER, 1977).

Water quality data available through STORET* have been tabulated in Appendix A for the major lakes in the Upper Oklawaha River Basin. While this does not represent a comprehensive listing of all available water quality data in the basin, it does provide a basis for evaluating the water quality conditions in the area of concern. Sources of data include the routine monitoring programs by DER and the U.S. Geological Survey, special studies such as the National Eutrophication Survey, and monitoring by local pollution control agencies. The locations of sampling stations are given in Figure 2.9.

Three lake groupings become apparent during analysis of the water quality data from the Upper Oklawaha River Basin Water Quality Management Plan (DER, 1977):

1. Lake Harris, Little Lake Harris, and Lake Yale generally have better water quality than the other lakes in the basin. These three lakes are not direct recipients of water from Lake Apopka as are Griffin and Eustis. Lake Harris, Little Lake Harris, and Lake Yale have moderate levels of BOD_5* and organic nitrogen*, with Lake Yale having the lowest values. All three have similar levels of inorganic nitrogen*, ammonia*, and phosphorus* (DER, 1977).

2. Lakes Griffin and Eustis form a second group with similar water quality. Connected by Haines Creek, they have received urban drainage and wastewater effluents. They are also the most distant from Apopka in the entire chain. Dissolved oxygen* and pH* levels in these two lakes are relatively high, indicating a substantial population of phytoplankton*. Values of BOD_5 and organic nitrogen are also relatively high, although ammonia and inorganic nitrogen values are somewhat lower in Lake Griffin. Levels of phosphorus appear to be lower in Lake Eustis than in Lake Griffin (DER, 1977).

3. Lakes Apopka, Beauclair, Carlton, and Dora exhibit the poorest water quality of the lakes in the Upper Oklawaha River Basin. Dissolved oxygen levels are frequently supersaturated and pH levels often exceed the upper standard of 8.5 for Class III waters. These conditions result

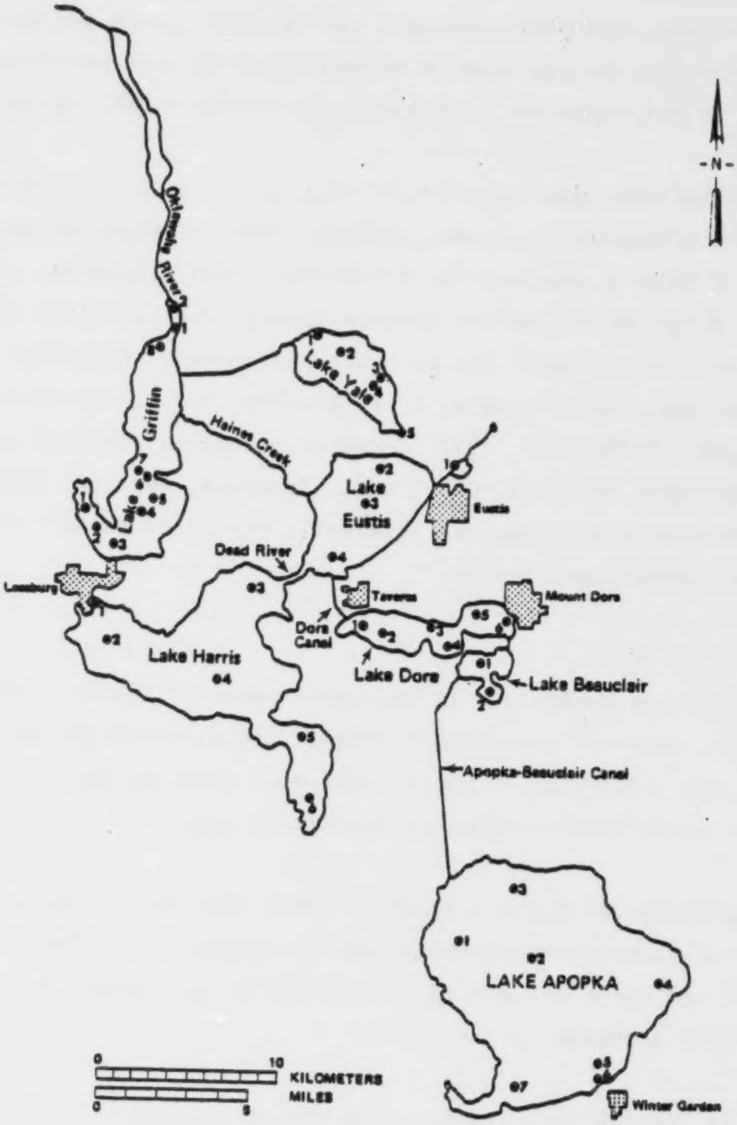
-N-
Oklawaha River
Lake Griffin
Lake Yale
Haines Creek
Lake Eustis
Eustis
Dead River
Leesburg
Tavares
Mount Dora
Dora Canal
Lake Harris
Lake Dora
Lake Beauclair
Apopka-Beauclair Canal
LAKE APOPKA
Winter Garden
0
10
KILOMETERS
MILES
0
5

Figure 2.9. Location of STORET Sampling Stations, Upper Oklawaha River Basin.

directly from excessive phytoplankton growth. Levels of BOD_5 and organic nitrogen are high, inorganic nitrogen and ammonia levels are generally low, and phosphorus levels usually exceed the 0.06 mg/l (milligrams per liter) used by the state as a desirable upper limit (DER, 1977).

Pesticides have been extensively used on the muck farms north of Lake Apopka. Consequently, some pesticide residues might be expected in the waters of Lake Apopka and the downstream lakes. However, a 1968-1971 study of the water quality of Lake Apopka (Forbes, 1971) found only traces of DDT (<0.001 mg/l) and no other pesticides. Pesticide analysis of muck farm canal water done by Post, Buckley, Schuh, and Jernigan, Inc. (Orlando), in October, 1977, found no pesticide residues at the level of detection employed, 0.001 mg/l (Thompson, personal communication). Pesticide residues are apparently not found in Lake Apopka water in any significant amount.

Wastewater Programs

Water quality conditions in the major lakes of the Oklawaha River Basin reflect years of excessive nutrient loadings from agricultural, municipal, and industrial sources. Abatement programs which are either complete or under construction are summarized below:

A. Agricultural Waste Abatement. This abatement program involves two groups of farmers--those whose land is inside the Zellwood Drainage District #2 and those whose land is outside of this area. Each group has about 3642 hectares (Woods, 1978).

Growers outside the district have larger acreages. In 1972, permits were issued to these farmers to conduct a plan for pollution abatement. Construction was well underway in 1973, as major farm units established recycling ponds for the containment of farm water pumpage and for subsequent irrigation water use. The last of these farms meeting the compliance schedule will do so by January, 1979. When construction is completed under this plan, 0.4 hectare of reservoir capacity will be provided for every 4 hectares under cultivation. The Institute of Food and Agricultural Sciences of the University of Florida has estimated that nutrient loadings have been reduced by 65 percent on those farms using retention basins. This figure was based on estimates that the total volume returned to the lake would be reduced by 50 percent and the nutrient concentration of the water within that discharge would be reduced by 30 percent.

Growers inside Zellwood Drainage District #2, some 27 different farmers, did not find it practical to construct separate holding ponds or recycling reservoirs on each farm. Therefore, they designed a different method for reducing the level of discharge of suspended solids and nutrients. The DER-approved plan will consist of (1) an 8361 m^2 (90,000 ft^2) basin for settling solids, (2) overflow weirs and flow deflectors for controlling and directing the flow to maximize solids removal efficiency within the settling basin, (3) provisions for removing the settleable solids and recycling them back to farmland, (4) a method for encouraging growth of water hyacinths in upland irrigation canals to provide absorption of dissolved nutrients, and (5) provisions for harvesting water hyacinths along the canal system and recycling them on farmland. It is calculated that this system will remove 50 percent of the suspended solids, 30 percent of the nitrogen, and 25 percent of the phosphorus being discharged to Lake Apopka (Post, Buckley, Schuh, and Jernigan, Inc., 1978). Under the terms of their state construction permit, the farmers of Zellwood Drainage District #2 will have until July 1, 1980, to complete this system and have it operating. According to a Central Florida Agricultural Institute spokesman, legal, engineering, and construction costs for these two abatement systems will rise above $840,000.

B. Citrus Processing Abatement. The Winter Garden Citrus Cooperative processes citrus fruit into concentrate form. Prior to 1969, the processing plant discharged 18,925 m^3 (5 million gal) per day of refrigeration cooling water and 7570 m^3 (2 million gal) per day of citrus waste into Lake Apopka. The citrus waste contained 3000 to 4000 ppm (parts per million) of BOD. By 1969, an activated sludge wastewater treatment plant was on line which reduced the BOD in the discharge by 90 percent. By 1977, the company had constructed percolation ponds and spray fields 11.3 km (7 miles) south of their plant location for further treatment of wastes. After this system became operational, the plant's discharge to Lake Apopka was limited to cooling water and small amounts of a condensation by-product. The cost of plant, pipeline, and pond construction was $2,030,000.

The plant's barometric condenser water and refrigerant cooling water are discharged into a drainage ditch about 1.6 km (one mile) from Lake Apopka. In order to evaluate the impact of this discharge on water quality, a dissolved oxygen model was developed for the drainage canal (DER, 1977). Because the first two sections of the canal provide good mixing through turbulence and fall, it was determined that an effluent with a BOD_5 of up to 90 mg/l can be assimilated under design conditions without depressing the dissolved oxygen in the drainage ditch below 5.0 mg/l. DER estimates that under present conditions, the Winter Garden Citrus Co-op contributes about 1.0 percent of the total annual nitrogen and phosphorus loads to Lake Apopka. (When the remaining muck farms reduce their input to the lake, the percentage contributed by the Co-op will rise to 1.8 percent of the annual nitrogen loading and 3.2 percent of the annual phosphorus loading.) The conclusion reached by DER was that there would be no significant improvement in water quality by removal of the remaining Winter Garden Citrus discharge.

Plymouth Citrus Products Cooperative is another plant discharging its barometric condenser and cooling waters into Lake Apopka. This discharge is made to Holts Lake, where water is retained and then recirculated for cooling. The overflow from Holts Lake goes into a ditch, then a swampy area, and finally drains into a canal within Zellwood Drainage District #2. Along this discharge route, a spring-fed canal provides further dilution. Because of the difficulty in separating the organic input of the citrus effluent from that of the natural swamp drainage or the farmlands of Zellwood Drainage District #2, a dissolved oxygen analysis of the discharge was not performed by DER. However, Plymouth Citrus took the major step of eliminating its stronger processing waste from the discharge at a cost of $1,417,193.

B. Domestic Waste Abatement. The City of Winter Garden, located on the south shore of Lake Apopka, is constructing a percolation ponding system which will eliminate the present direct discharge to Lake Apopka. Nitrogen will be removed by nitrification/denitrification. Phosphorus will be removed by chemical precipitation. The treated effluent will be discharged to percolation/evaporation ponds. Some groundwater seepage through underdrains is expected with this treatment method. However, until monitoring shows the extent of this seepage, only water treated to advanced stages will be placed in the percolation ponds. Monitoring wil take place quarterly as per Florida Administrative Code (FAC) 17-19, but may be increased in frequency at the discretion of DER. Samples will be taken at the underdrain discharge and tested as per FAC 17-19 including tests for fecal coliform, BOD_5, total nitrogen and chloride. This system, including design, will cost $4,616,500 by the time of its completion in 1979.

Biology

The concentrations of various pollutants and nutrients in a body of water are easily measured. However, the effects of these substances upon living organisms are less easily determined, and the presence or absence of certain organisms often depends on the water quality of a given body of water.

Flora

A. Macrophytes*. The first published account of the aquatic vegetation in Lake Apopka (Clugston, 1963) indicates that until 1946, the extremely clear water supported abundant plant life. Pondweed (Potomogeton illinoensis) formed massive beds beginning 180 m (200 yd) offshore and continuing lakeward to depths of 2.4 m (8 ft). These beds covered an estimated 8100 hectares (20,000 acres) or more (FG&FWFC, 1974). However, by 1950 this species of plant could not be found in Lake Apopka (Clugston, 1961).

In 1959 a thick band of panicgrass, maidencane, spike rush and eelgrass (Panicum geminatum, Panicum hemitomon, Eleocharis sp. and Vallisneria americana) respectively bordered most of the lakeshore from the area of Winter Garden west to Oakland (Clugston, 1961). A 1973 survey found only a few sparse patches of stonewort (Chara) and Panicum in this same area (FG&FWFC, 1974).

Concerning the area between Pine Island and Smith's Island, Clugston (1961) commented, "The first mile (1.6 km) of this shoreline was unusual in that it was bordered almost continuously by a strip of panicgrass and maidencane about 10 yards (9.1 m) wide,"... eelgrass "was common between the panicgrass and the shore." In 1973 only scattered strands of Panicum were found along the northeast shore of Pine Island (FG&FWFC, 1974).

These few examples serve to demonstrate the incredible changes that have taken place in the aquatic vegetation of Lake Apopka in a relatively short time. The suspected causes for these changes, discussed in the section entitled Lake Apopka History, include nutrient inputs from Winter Garden sewage, wastes from citrus processing plants, drainage from muck farms, attempts at controlling water hyacinths (Eichhornia crassipes) through spraying of herbicides, and vegetation damage caused by the 1947 hurricane.

Within the past several years various pollution abatement programs have dramatically reduced the amount of nutrients entering the lake. The water hyacinth control programs, while still in effect, do not involve spraying on a scale as was performed in the 1940-50's. Although hurricanes have passed through the area in recent years, they have not reached the magnitude of the 1947 storm. In any case, little vegetation was present in the lake which could have been damaged by the more recent storms.

In spite of these apparent improvements, the amount of rooted vegetation in the lake has continued to decline. Between the years 1973 and 1977, FG&FWFC personnel made three surveys of the aquatic vegetation on the Upper Oklawaha Basin. The areas covered by six species of macrophytes important to fisheries were measured and recorded. These data for Lake Apopka are presented in Table 2.6. The FG&FWFC (1977) concluded that, "Measurements of aquatic plants, considered important to the maintenance of desirable sports fisheries... revealed a continuing loss of macrophytes from Lake Apopka... At study termination important rooted vegetation was present on only 0.03 percent of the area of Apopka..."

Table 2.6. The Area Covered by Various Plants in Lake Apopka.[1]

	Area Covered in Hectares		
Plant	73-74	75-76	76-77
Panicum spp.	0.53	0.55	0.44
Typha spp.	-	-	-
Scirpus californicus	24.69[2]	5.30	2.67
Sagittaria sp.	-	-	-
Pontederia sp.	-	-	-
Cladium jamaicensis	-	-	-
Nuphar advena	0.69	0.24	0.12
Scirpus americanus	0.00	0.00	0.00
Valisneria americana	0.00	0.00	0.04
Chara vulgaris	0.24	0.40	0.65
Eleocharis cellulosa	0.00	0.00	0.00
Total Hectares	26.14	6.48	3.92
% of Lake Surface Area	0.21	0.05	0.03

[1] figures were not recorded for four species of marginal vegetation because their location and growth form at the time of the study were deemed unimportant to fisheries biology.

[2] figure exaggerated due to rangefinder malfunction (FG&FWFC, 1976).

Source: FG&FWFC, 1977. Study I. Upper Oklawaha Basin Fisheries Investigation, F-30, 1973-1977.

There are three basic reasons for the lack of improvement in aquatic vegetation since the lake's decline:

1. Nature of bottom material in Lake Apopka. In the years before Lake Apopka's decline, high nutrient input promoted the growth of vast amounts of aquatic vegetation. The sudden death and decay of this vegetation due to damage by the 1947 hurricane and due to hyacinth spraying, in addition to rapidly accumulating organic deposits resulting from the death of algae, resulted in a thick layer of muck on the lake bottom. Although Lake Apopka has always had a muck bottom, the additional muck was apparently enough to inhibit the growth of rooted aquatic vegetation. Macrophytes are unable to form a secure attachment to the muck and tend to uproot with only little agitation. In some areas sand is exposed and plants are able to germinate but are soon covered and smothered by the fluid-like muck (_FG&FWFC_, _personal communication_).

2. Limitation of light passing through the water of Lake Apopka. After the hurricane, the decay of the aquatic vegetation released enormous amounts of dissolved nutrients into the water. Before the remaining slow-growing macrophytes were able to utilize these nutrients, the fast-growing phytoplankton* used them to reproduce rapidly, creating, in the fall of 1947, the first recorded algal bloom for Lake Apopka. Since the early 1950's the lake has had an almost perpetual algal problem. During an algal bloom the density of algal cells is so great that it blocks a great deal of sunlight that would normally pass through the water to the macrophytes growing below. The shading effect of the algal bloom hinders the growth and survival of rooted aquatic vegetation. A further source of shading comes from floating mats of water hyacinths.

3. Artificial stabilization of water level. Under natural conditions virtually all Florida lakes undergo seasonal fluctuations in water level. Native aquatic vegetation has adapted to these conditions to the point that the seeds of many of these plants must undergo drying and subsequent resubmersion in water before they

can germinate. In addition, as the water level decreases, light is able to penetrate the shallower water and plants are able to establish themselves further from the original shoreline, thus increasing the vegetated littoral zone. With the building of water control structures and subsequent stabilization of the lake level, the zone of aquatic vegetation has decreased.

B. Phytoplankton. These algae, like all other plants, are able to manufacture food materials out of carbon dioxide and water, using energy from sunlight in an internal biochemical process called photosynthesis. Primary productivity is a measure of the amount of photosynthesis taking place. In a lake primary productivity is measured in weight of carbon (from carbon dioxide) consumed by the phytoplankton in a cubic meter of water taken from that lake during one hour of photosynthesis ($mgC/m^3/hr$). Productivity is directly related to the degree of enrichment of a body of water.

In Lake Apopka primary productivity values have been measured at 736.6 $mgC/m^3/hr$ (Anon., 1969) and 852 $mgC/m^3/hr$ (Dept. Envir. Eng. Sci., 1977), the highest in the Oklawaha Chain of Lakes. This level of productivity is indicative of a highly eutrophic lake.

Food materials produced during photosynthesis are used by algae in their own growth and reproduction. When consumed by an animal some of these materials are used in the growth and reproduction of that animal. As predators eat these animals, some of the same food material is again passed on. Thus, the algae serve as the basic source of food in lakes. However, the presence of some phytoplankton, specifically blue-green algae (Cyanophyta), negatively affects the growth and reproduction of many other organisms. Under certain conditions, the blue-greens are able to out-compete other phytoplankton species, thus becoming the dominant algae in the body of water. Since many animals are unable to utilize blue-green algae as a food, and because many blue-greens produce toxins injurious to other organisms, the density of some animal populations may be reduced.

Surveys of Lake Apopka (Biederman, 1978) showed the algae of the lake are dominated by five species: Lyngbya lagerheimii, Lyngbya limnetica, Microcystis incerta, Spirulina laxissima and Schizothrix calcicola. All five of these species are blue-green algae.

In addition to manufacturing food materials, the process of photosynthesis produces oxygen which, in aquatic systems, is released into the water as dissolved oxygen. Algae produce more oxygen than they use only when exposed to ample light. At night they cannot photosynthesize and thus they use more oxygen than they produce. This phenomenon causes a 24-hour cycle of rising and falling dissolved oxygen concentration.

Additionally, many algal cells are slightly denser than fresh water and tend to slowly sink towards the bottom if not suspended by turbulence. Once the cell sinks below the level at which light is able to penetrate (usually about 0.25 m in Lake Apopka) it must consume stored food supplies and will die when these supplies are exhausted. Bacteria, while in the process of decomposing the dead algae cells, consume oxygen and release nutrients for new algae to utilize. During an algal bloom the amount of dead matter and subsequent bacterial action is so great that almost all of the oxygen in the water can be used up. This sequence of events has been the cause of massive fish kills in many lakes.

Although Lake Apopka has had a perpetual algal bloom since the early 1950's, limited data, collected by various scientists from 1967 to 1977, have not indicated any serious oxygen depletion. Because Lake Apopka is so shallow and has such a large surface area, mixing by wind replaces oxygen-depleted bottom water with oxygen-rich surface water. This water circulation, however, does not greatly affect the sediment-water interface which remains without oxygen, as evidenced by the strong sulfur smell when muck is brought to the surface. Decaying algae add to the flocculent, fluid-like muck and further limit the capability of the lake bottom to support many forms of life (See Macrophytes, page 45 and Benthos, page 54).

Paradoxically, oxygen, while required by all animals, is toxic when its concentration exceeds a certain level. During an algal bloom the production of oxygen can become so great that the water becomes supersaturated with dissolved oxygen. In fish this supersaturation may produce a disease called gas embolism. This disease is characterized by the formation of gas bubbles in blood vessels of the fish, resulting in a weakened condition or death. Although the reasons for massive fish kills are often disputed, gas embolism was suspected to be the cause of death of 453,600 kg (1,000,000 lb) of shad in Lake Apopka in May, 1963 (Fla. State Board of Health, 1964).

C. Bacteria. These microbes play several important roles in the aquatic ecosystem*. Certain bacteria are directly responsible for the decay of dead animal and plant materials, a process which releases nutrients from the dead material for use by living organisms. As mentioned previously, these bacteria may also be responsible for depleting the water of its oxygen. A second diverse group of bacteria is involved in the nitrogen cycle, changing nitrogen gas into ammonia, nitrites into nitrates and vice versa. The third group, the parasitic bacteria, is the one that has earned bacteria their unpopular reputation. These microbes live in the bodies of other organisms and are most often associated with sanitation, pollution and disease problems.

As humans, we are primarily interested in the parasitic bacteria. Almsot all water-borne bacteria that might cause a human disease are infective through the consumption of water containing those bacteria. These microbes then live in the intestine, returning to a body of water in fecal matter from an infected human.

Disease-carrying bacteria cannot be directly isolated from contaminated water because they are present in relatively small numbers. However, one bacterium, Escherichia coli (E. coli), is a constant inhabitant of the human intestinal tract. Although it does not cause disease, its presence in water indicates fecal contamination and, thus, the possible presence of disease-causing bacteria. Consequently, a determination of the density of these bacteria is important to human health.

Commonly, two measures of bacterial contamination are made. The total coliform count includes some _E_. _coli_-like bacteria washed from the soil and _E_. _coli_. The fecal coliform count indicates the number of _E_. _coli_ originating only from the intestines of warm-blooded animals.

In 1963, during previously mentioned fish kills, the total coliform count in Lake Apopka was quite high, 600/100 ml to 10,000/100 ml of water (Orange Co. Health Department, 1963). In 1970-71, total coliform counts varied between 250/100 ml and 2650/100 ml of water, while fecal coliform counts ranged from 100/100 ml to 550/100 ml of water (Henley and Chestnut, 1971). While the bacteria content of Lake Apopka is quite high, it generally does not exceed the standards set for Class III waters by Section 17-3.09, Florida Administrative Code. Within the Oklawaha Chain of Lakes, Lake Apopka had the highest total coliform count. The total coliforms in the remaining lakes generally decreased as a function of distance from Lake Apopka (Henley and Chestnut, 1971).

An additional bacterial consideration in Lake Apopka is the presence of _Aeromonas_. The Florida Epidemiology Research Center indicates that _Aeromonas_ is found in virtually all Florida lakes (Olsen and French, 1976). Although there are few documented cases of _Aeromonas_ infection in humans, it was the suspected cause for a 1971 alligator/fish kill in Lake Apopka. While many biologists doubt that _Aeromonas_ was the cause of the kill, this bacteria does attack already weakened animals.

Fauna

A. Zooplankton*. Zooplankton of lakes are usually composed of only a few species, but the number of individuals of some of these species can be large (Odum, 1971). Most zooplankton are highly transparent invertebrates*. The largest species exceed 1 mm in length and are thus visible to the unaided eye. Others range downward in size from barely visible to microscopic.

Many zooplankters are filter feeders, straining phytoplankton, bacteria, and other small particles from the water. Others are predators, feeding on smaller species of zooplankton.

By grazing on phytoplankton, zooplankton convert the food substances manufactured by phytoplankton into zooplankton tissue. Zooplankton can in turn be consumed by fish, thus passing energy originally produced by phytoplankton to organisms of direct importance to man. Grazing by zooplankton can also regulate population densities of phytoplankton (Hrbacek et al, 1961). Thus, a collection of organisms seldom seen by anyone but biologists forms an important link in a lake's ecosystem.

Zooplankton populations in Lake Apopka and the Oklawaha Chain of Lakes were monitored during 1977 by Univeristy of Florida personnel. Analysis of these data is not yet completed, but results from April and May are summarized in Table 2.7.

Table 2.7. Zooplankton from 10 Stations in Lake Apopka During Spring, 1977.

	April Range		May Range	
	(No./liter)	(% of total)[1]	(No./liter)	(% of total)[1]
COPEPODA				
Diaptomus dorsalis	0.7-3.0	4.8-13.7	8.7-120	28.8-48.5
Cyclops sp.	0.24-27	0.6-6.5	2.4-37	2.12-14.8
CLADOCERA				
Daphnia ambigua	0-19	0-6.5	0-17	0-7.8
Bosmina longirostris	1.17-347	74.3-88.6	8.8-88	32.7-46.1
ROTIFERA				
Brachionus havaneansis	0-25	0-2.3	0-7	0-3.8
Asplanchna sp.	0-1.5	0-1.1	0-6	0-3.1
Keratella cochlearis	0	0	0-4	0-1.7

[1] The % of the total zooplankton collected represented by each species.

Source: University of Florida, Department of Environmental Engineering Sciences.

In April, *Bosmina longirostris* (Cladocera) heavily dominated the zooplankton, usually comprising more than 75 percent of the total population and reaching densities of 347/liter. Dominant populations of *B. longirostris* have been reported in other nutrient-rich lakes (Deevey and Deevey, 1971). In May, *B. longirostris* shared dominance with *Diaptomous dorsalis* (Copepoda), each usually composing about one-third of the total population. In both months none of the other species routinely exceeded 10 percent of the total.

In a preliminary presentation of results from the remaining months of the zooplankton study, Mallin (1978) reported that rotifers during the summer increased in number of species and in abundance. Cladocerans peaked during spring and mid-winter. Throughout the study, Lake Apopka had higher populations of zooplankton than the downstream lakes. The perpetual blooms of phytoplankton in Lake Apopka are apparently supporting these higher populations of zooplankton.

In Table 2.7 the paucity of species composing the zooplankton in Lake Apopka is apparent. Other investigators have noted that zooplankton diversity in Florida lakes, regardless of the lake's water quality, is generally low (Cowell, personal communication).

B. Benthos*. Benthic invertebrates are nearly unknown to casual recreational users of lakes, yet a healthy lake ecosystem includes a diverse and abundant assemblage of invertebrates living on and in the bottom sediments. Benthic invertebrates are important components of a lake's ecosystem. Some feed on decaying plant and animal matter, thus contributing to the recycling of nutrients. Others feed directly on living plants, thereby forming the first link in the transfer of photosynthetically-produced food to the food web*. Regardless of their own manner of feeding, benthic invertebrates compose a substantial part of the diet of many species of fish, including game fish.

The FG&FWFC (1976) monitored populations of benthic invertebrates in the Oklawaha Chain of Lakes during 1973-1976. Results for Lake

Apopka are presented in Figure 2.10. Samples were taken periodically in two areas of the lake (one southwest, the other southeast) along a line from the shore (19.8 m MSL) outward at 0.3 m intervals of bottom elevation. Data in the figure are yearly averages of both stations for each interval and are reported as #/.09 m^2 (the area of bottom covered by each sample). The highest populations occurred in shallow water near the shore, and number collected decreased sharply with depth. The small amount of rooted vegetation left in Lake Apopka is confined to shallow areas, and high densities of benthic invertebrates are often associated with rooted vegetation. In such a habitat, invertebrates are provided with a rich food base (living and decaying plant material) and protection from predators. Most of the bottom of Lake Apopka lacks macrophytes and is smothered by a layer of unconsolidated organic matter continually shifted by wave action (discussed in detail in the Flora section). Biological and chemical decomposition of the muck's high organic content results in low oxygen concentrations at the sediment-water interface. Thus, much of the bottom of Lake Apopka is not a suitable habitat for a diverse assemblage of invertebrates.

Table 2.8 contains a list of the types of invertebrates collected in Lake Apopka in 1975-1976. Although the list is reasonably diverse, only three groups, oligochaetes (aquatic earthworms), chironomid larvae (midges), and amnicolid snails, were collected regularly and in any abundance. In fact, 80-90 percent of the invertebrates collected in Apopka were oligochaetes or snails, with the snails reaching densities of 24,000/.09 m^2. These two groups feed on organic sediments and are quite tolerant of the oxygen-poor conditions in Lake Apopka. If oligochaetes and snails were removed from Figure 2.10, benthic densities would be much lower.

The other lakes in the chain had less abundant benthic populations than Apopka, but the diversity of the benthos was greater. In addition, dominant species in the downstream lakes were chironomids and amphipods (scuds). These are important fish food organisms, but the oligochaetes and amnicolids dominating the benthos of Apopka are not. Thus, even

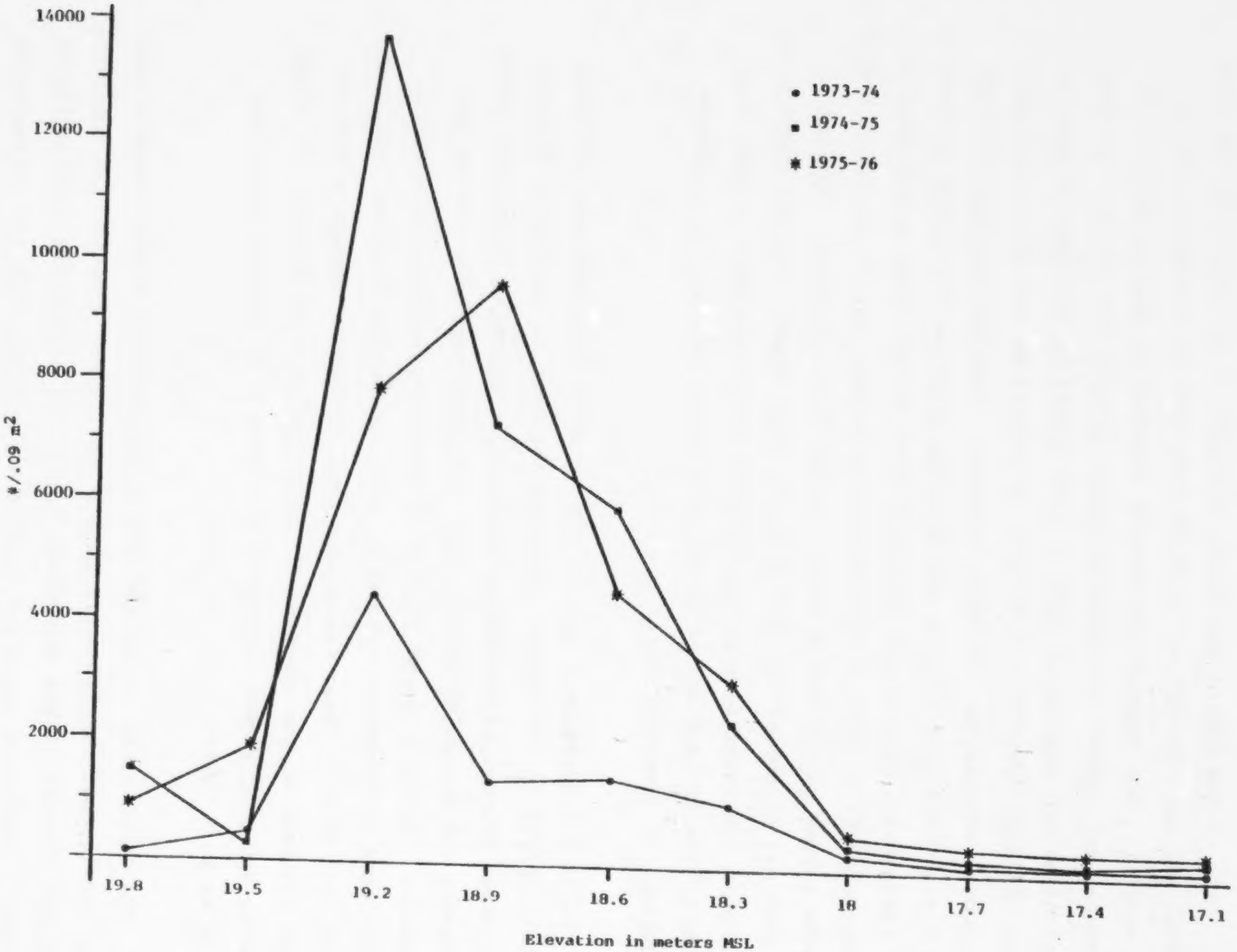

Figure 2.10. Average Number of Organisms per .09 m^2 of Substrate in Lake Apopka for Combined Sampling Areas and Periods, by Elevation.

Table 2.8. A list of invertebrates collected in Lake Apopka, 1975-1976

Classification	Common Name
Class: Turbellaria	
Order: Tricladia	
Family: Planariidae	flatworms
Phylum: Nematoda	roundworms
Class: Oligochaeta	aquatic earthworms
Class: Hirudinea	
Order: Rhynchobdellida	
Family: Glossiphoniidae	leeches
Order: Arhynchobdellida	
Family: Erpobdellidae	leeches
Class: Crustacea	
Order: Branchiura	
Family: Argulidae	fish lice
Order: Amphipoda	
Family: Talitridae	scuds
Order: Decopoda	
Family: Palaemonidae	freshwater shrimp
Class: Insecta	
Order: Ephemeroptera	
Family: Baetidae	mayflies
Order: Odonota	
Family: Gomphidae	dragonflies
Family: Coenagrionidae	damselflies
Order: Hemiptera	
Family: Mesoveliidae	water treaders
Family: Corixidae	water boatmen
Order: Trichoptera	
Family: Leptoceridae	caddis flies
Order: Diptera	
Family: Culicidae	phantom midges
Family: Chironomidae	midges
Family: Ceratopogonidae	biting midges
Class: Gastropoda	
Order: Pulmonata	
Family: Physidae	pouch snails
Family: Planorbidae	orb snails
Order: Ctenobranchiata	
Family: Amnicolidae	operculate snails
Family: Viviparidae	round-mouth snails
Class: Pelecypoda	
Order: Eulamellibranchia	
Family: Sphaeriidae	fingernail clams

Source: FG&FWFC, 1976. Study I. Oklawaha Basin Fisheries Investigations. F-30-1, 1975-1976.

though more energy is probably transferred from organic sediments to animal tissues (benthic invertebrates) in Lake Apopka than in the downstream lakes, relatively less of this energy may end up in fish species of direct importance to man.

C. Fish. Fish populations in Lake Apopka have been periodically monitored by FG&FWFC personnel for more than two decades. These studies have documented a transformation from a productive, game fish-dominated fishery to a system dominated by species of rough fish (FG&FWFC, 1977).

During the middle 1970's, FG&FWFC personnel studied fish populations in Lakes Apopka, Dora, and Griffin (FG&FWFC, 1977). Sampling was by 0.4 hectare (1.0 acre) block-off nets with a fish poison used to kill fish within the net. Four littoral and three open water samples were taken in Lake Apopka each fall and spring during the study period.

Table 2.9 is a list of fish species collected in Lake Apopka during 1974-1976. Species are partitioned into three categories, sport fish, forage (prey), and other, according to a system developed by the FG&FWFC (1976). The list contains 24 species, six less than collected in Lake Dora and eight less than in Lake Griffin. In all three lakes more species were collected in vegetated littoral areas than in open water areas.

The number, percentage compositions, and weights of each of the three categories of fish are presented in Table 2.10. Data are entered as averages for samples taken in the littoral and open water areas of Lake Apopka (four and three samples per season, respectively). In most sampling periods and in both littoral and limnetic areas, the fish population was heavily dominated by forage fish. During all sampling periods, the largest contributors to forage fish in both number and weight were the two species of shad. Shad are considered rough fish with commercial value only as crab bait or when processed into animal food.

The increase in sport fish number and weight in the littoral area in spring 1976 actually resulted from a recovery in the population of a single species, black crappie. Populations of all other species of sport fish either declined or remained stable.

Table 2.9. A List of Fish Species Collected in Lake Apopka, 1974-1976. Species are Assigned to Categories According to FG&FWFC (1977).

Common Name	Family	Species
Sport fish		
warmouth	Centrarchidae	*Lepomis gulosus*
bluegill	Centrarchidae	*L. macrochirus*
redear sunfish	Centrarchidae	*L. microlophus*
largemouth bass	Centrarchidae	*Micropterus salmoides floridanus*
black crappie	Centrarchidae	*Pomoxis nigromaculatus*
Forage		
tidewater silverside	Atherinidae	*Menidia beryllina*
blue tilapia	Cichlidae	*Sarotherodon aureus*
gizzard shad	Clupeidae	*Dorosoma cepedianum*
threadfin shad	Clupeidae	*D. petenense*
golden shiner	Cyprinidae	*Notemigonus crysoleucas*
taillight shiner	Cyprinidae	*Notropis maculatus*
Seminole killifish	Cyprinodontidae	*Fundulus seminolis*
bluefin killifish	Cyprinodontidae	*Lucania goodei*
mosquito fish	Poeciliidae	*Gambusia affinis holbrookii*
least killifish	Poeciliidae	*Heterandria formosa*
Other		
bowfin	Amiidae	*Amia calva*
American eel	Anguillidae	*Anguilla rostrata*
Atlantic needlefish	Belonidae	*Strongylura marina*
white catfish	Ictaluridae	*Ictalurus catus*
yellow bullhead	Ictaluridae	*I. natalis*
brown bullhead	Ictaluridae	*I. nebulosus marmoratus*
tadpole madtom	Ictaluridae	*Noturus gyrinus*
longnose gar	Lepisosteidae	*Lepisosteus osseus*
Florida gar	Lepisosteidae	*L. platyrhincus*

Source: FG&FWFC, 1977. Study I. Upper Oklawaha Basin fisheries investigation. Final Report. F-30.

Table 2.10. Average Number, Kilograms[1], and Percentage Compositions for each Category of Fish Collected in Lake Apopka in Littoral (L) and Open Water (O) Areas. Categories Are Expanded in Table 2.12.

	SPORT FISH				FORAGE				OTHER			
FALL 1974												
	No.	%	Kg.	%	No.	%	Kg.	%	No.	%	Kg.	%
L	744.6	16.6	14.1	18.6	3,114.6	69.5	33.7	44.5	619.8	13.8	28.0	36.9
O	174.0	8.2	3.3	11.7	1,917.7	90.2	23.5	82.3	33.3	1.6	1.7	6.0
SPRING 1975												
L	663.4	31.1	27.0	29.8	1,314.9	61.7	44.6	49.2	154.1	7.2	19.0	21.0
O	260.7	17.4	2.6	12.7	1,134.0	75.8	16.7	82.8	100.7	6.7	.9	4.5
FALL 1975												
L	938.7	39.4	13.1	21.1	1,169.2	49.1	40.9	65.8	275.1	11.5	8.1	13.1
O	163.0	16.2	2.8	17.2	818.7	81.5	12.6	76.8	23.0	2.3	0.9	6.0
SPRING 1976												
L	611.4	43.5	47.7	48.7	528.1	37.6	19.8	20.2	265.7	18.9	30.5	31.1
O	82.0	14.5	1.4	5.7	388.4	68.5	21.7	85.5	96.3	17.0	2.3	8.8

Source: FG&FWFC. 1977. Study I. Upper Oklawaha fisheries investigation. Final report. F-30.

[1] Conversion factor: kilograms multiplied by 2.2 equal pounds.

The decline over the past 25 years in the populations of all sport fish but black crappie can be most directly attributed to changes in the character of the bottom sediments of Lake Apopka. These sport fish species hollow out shallow depressions in a firm substrate, deposit and fertilize their eggs, and then protect them until hatching. The constantly shifting, unconsolidated sediments covering much of the bottom are not suitable for this method of reproduction. Fish species currently dominating in Lake Apopka are not as dependent on a firm bottom (Bill Johnson, FG&FWFC, personal communication).

The tremendous reduction in the vegetated littoral zone of Lake Apopka also contributed to the decline of the sportfishery. The vegetation provided protection for juvenile sport fish as well as food and cover for a variety of fish-food organisms. Most of the bottom of Lake Apopka would be classified as an open water area. These open water areas are extremely unproductive for sport fish and "other" fish (Table 2.10). Excepting black crappie, sport fish were only rarely collected in open water. Shad inhabit open water, and this explains the relatively higher production of forage fish in those areas.

As discussed previously, much of Lake Apopka lacks a diverse and abundant benthic fauna. Since many benthic species are fish food organisms, this further retards the sportfishery.

An additional negative factor affecting the sport fish populations of Lake Apopka is competition with gizzard shad (FG&FWFC, 1974). The nature of this competition is poorly understood, but in Florida lakes dense populations of gizzard shad are usually associated with low populations of sport fish. The situation may begin when a decline in sport fish (for any of the reasons discussed above) reduces predation pressure on gizzard shad. The shad population then begins to expand, and more shad reach a sufficiently large size to avoid being preyed upon by sport fish. Then, instead of being a food resource for sport fish, gizzard shad become competitors, further reducing sport fish populations.

A better understanding of the competitive relationship between shad and sport fish populations will come with greater knowledge of the diet of gizzard shad. Although most studies of the diet of gizzard shad have indicated that the species feeds on plankton, some have suggested that bottom feeding is more important (FG&FWFC, 1974). In fact, Freeman and Huish (1953) concluded that gizzard shad in Lakes Eustis and Harris were bottom feeders and competed with sport fish (bluegill and redear sunfish) for food.

The downstream lakes (Dora and Griffin) in the 1973-1977 FG&FWFC study had considerably higher production of sport fish than did Lake Apopka. These lakes had greater areas of vegetated littoral zone, more diverse populations of benthic invertebrates, and bottom sediments suitable for sport fish spawning. All of these factors contributed to the maintenance of healthier sportfisheries in Lakes Dora and Griffin.

D. Semi-aquatic vertebrates*. Lake Apopka has substantial populations of alligators, turtles, water snakes, and various amphibians. All of these species interact with other components of the lake's ecosystem, but no qualitative or quantitative studies are available from the lake area on these organisms.

Ecosystem Relationships

The interrelationships among the organisms of a community are complex. Organisms depend upon one another for food, protection, habitat, etc. Figure 2.11 diagrams the previously discussed events that led to Lake Apopka's current condition. This figure and the following outline demonstrate the complexity of an ecosystem. Changes in each component of the system have affected virtually all other components of the system.

Prior to 1947, a substantial portion of the nutrients introduced into Lake Apopka from outside sources were tied up in the tissues of macrophytes. The 1947 hurricane and the hyacinth spraying programs caused the death of massive amounts of aquatic vegetation, resulting in a thick layer of decaying organic matter on the lake bottom and a tremendous release of nutrients into the water. Rapidly growing phytoplankton quickly used these nutrients resulting in Lake Apopka's first algal bloom in the fall of 1947. Dead algal cells from this and subsequent

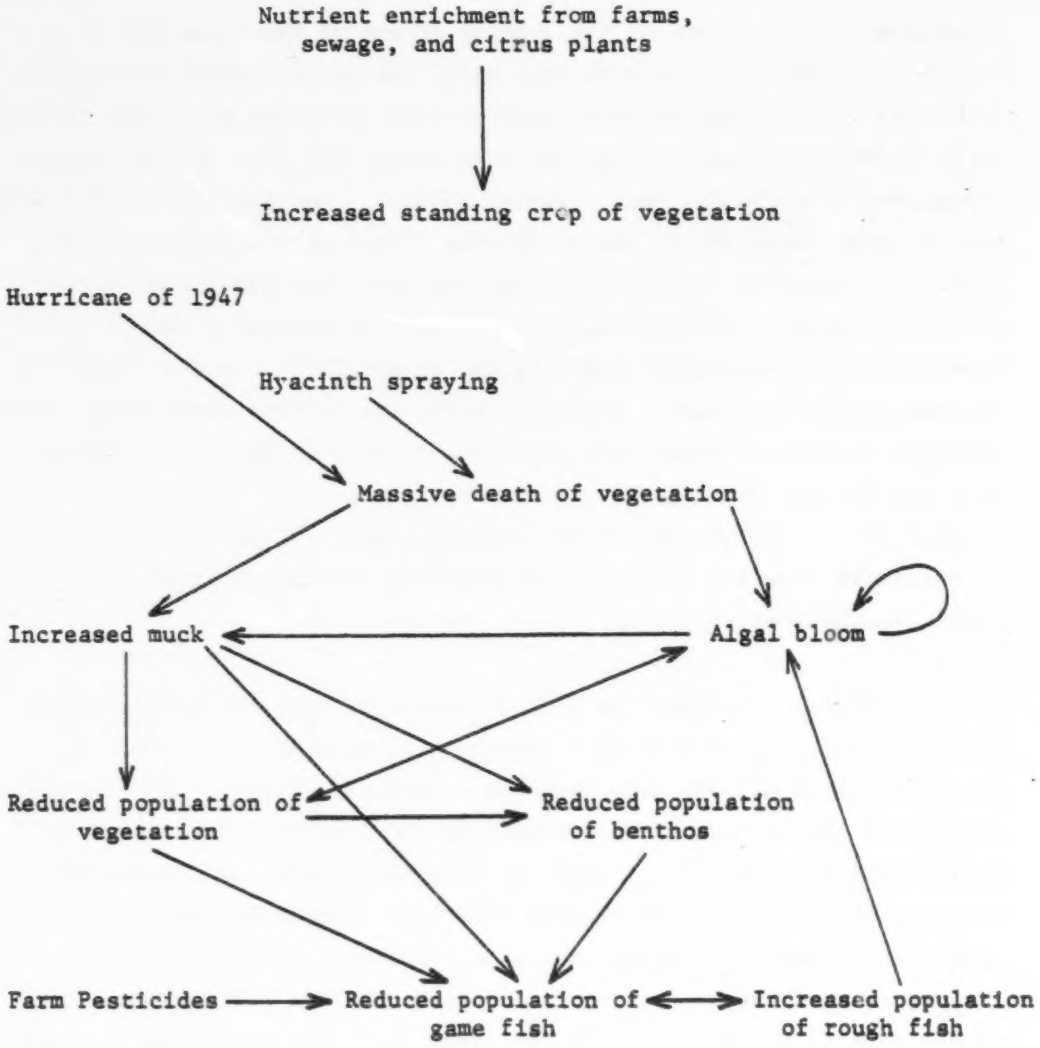
Nutrient enrichment from farms, sewage, and citrus plants
Increased standing crop of vegetation
Hurricane of 1947
Hyacinth spraying
Massive death of vegetation
Increased muck
Algal bloom
Reduced population of vegetation
Reduced population of benthos
Farm Pesticides
Reduced population of game fish
Increased population of rough fish

Figure 2.11. Physical and Ecological Events Leading to Lake Apopka's Current Conditions.

blooms released nutrients for future blooms while adding to the unconsolidated muck layer. Due to the shading effect of the algae and to rooting difficulties caused by this muck, the aquatic vegetation never recovered. Since many benthic invertebrates and young game fish relied on rooted macrophytes for food and protection, the densities of these two groups of organisms were likewise reduced. The benthic invertebrates were further inhibited by the smothering effect of the anaerobic muck. Additional negative factors affecting the game fish population were: (1) reduction of food supplies from the benthic community and (2) interference with reproduction caused by the unconsolidated muck. With reduced predation pressure from game fish, the population of rough fish began to increase. Older, and therefore larger, rough fish competed with and further reduced the population of game fish. In addition, some rough fish are thought to act as nutrient pumps, aiding in the release of nutrients from the sediments and possibly causing an increase in algal growth (Shapiro, 1975).

A food web describes the flow of energy or food materials through an ecosystem. Figure 2.12 is a very general diagram of the flow of these nutrients through Lake Apopka's ecosystem. Figure 2.12, although relatively simple, serves to demonstrate the complex nature of a food web. Among the eight categories are 32 interactions. An interaction consists of a one-way flow of food materials between any two categories. Flow within each category has not been considered in this simple web, although such flows are important. A more detailed diagram would have broken each of the eight groups in Figure 2.12 into individual species and would have presented quantitative data. In addition to requiring several pages of diagrams with complicated notation, this type of precision has rarely been attained with our current knowledge of feeding ecology.

While Figure 2.12 is easily understood by following the lines from the output of one category to the input of another, several points should be emphasized. Certain bacteria obtain energy and nutrients for growth through the decomposition of dead organisms and muck. The muck is not an organism and does not use food materials as the web might suggest; muck is merely a nutrient pool receiving organic material from the biological wastes and dead organisms from each living category. In

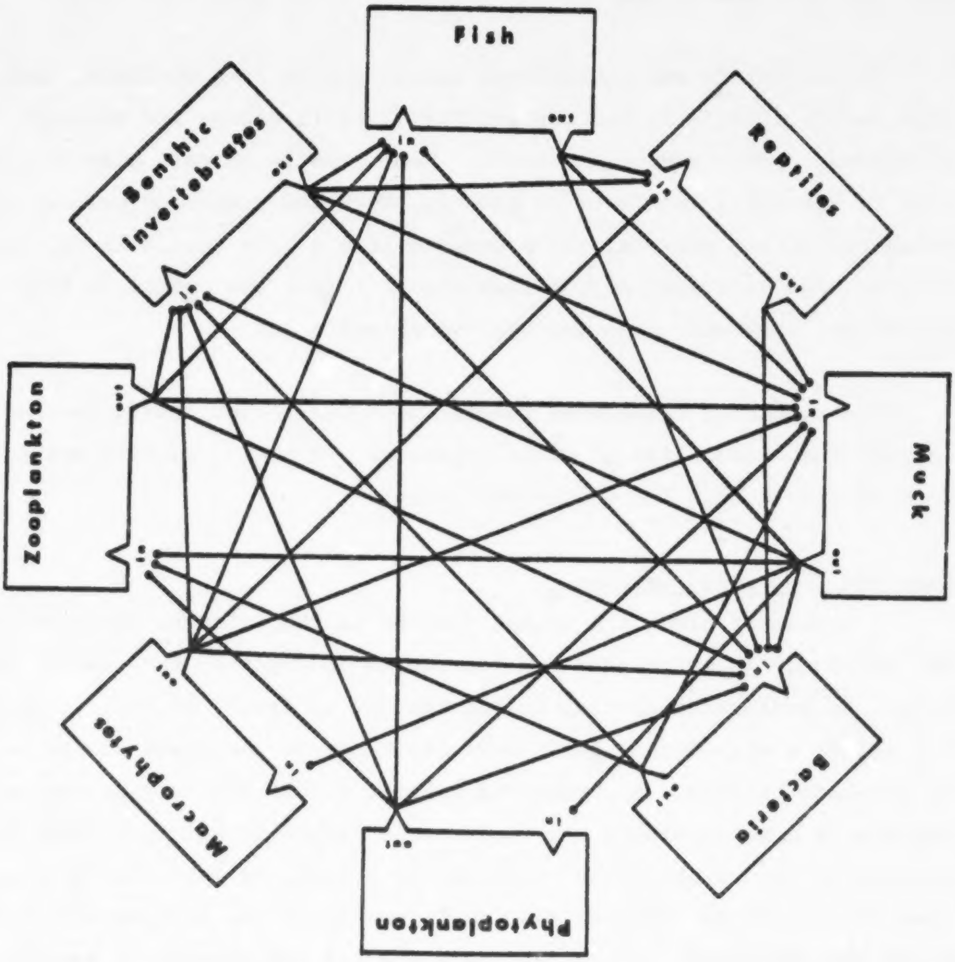
Fish
Reptiles
Muck
Bacteria
Phytoplankton
Macrophytes
Zooplankton
Benthic Invertebrates
in
out

Figure 2.12. Food Web for Lake Apopka.

Lines indicate flow of food materials among various categories of organisms and muck.

addition, the muck and bacteria receive nutrients from sources outside the lake. These unlisted sources include terrestrial vegetation blown into the lake and organic matter washed into the lake from soils.

Phytoplankton and macrophytes obtain energy from sunlight, carbon from carbon dioxide in the air and dissolved in water, and nitrogen and phosphorus from the muck and water. Some aquatic animals play an indirect role in providing nutrients to plants. Muck and suspended solids, when eaten by certain animals, are processed into a form available to plants. However, the nutrients do not come directly from the animal in this situation; they only pass through the animal's gut.

The remaining categories consist of animals that obtain food materials through the consumption of other organisms and muck. Animals use these food materials both for energy and growth.

Rare and Endangered Species

A number of plant and animal species in the Oklawaha Chain of Lakes and surrounding countryside are considered endangered, threatened, or rare. An endangered species is one that is in danger of extinction throughout all or a significant portion of its range in the state due to natural or man-made factors. A threatened species is one that may become an endangered species within the foreseeable future in all or a significant portion of its range in the state due to natural or man-made factors. The Florida Audubon Society and Florida Defenders of the Environment recognized two additional categories, rare species and species of special concern. A rare species, as defined here, is not presently endangered or threatened but is potentially at risk because it is found only within a restricted geographic area or is sparingly distributed over a more extensive range. A species of special concern does not clearly fit into one of the above categories, yet, for certain reasons, deserves special attention.

Table 2.11 is an inventory of endangered, threatened, rare, and special concern species in the project area. General sources for this information included the Orlando Metropolitan 208 Plan, the Lake County Comprehensive Plan, and the Water Resource Management Plan of the St. John's River Water Management District. Other confirming sources are cited when appropriate.

Human Health Hazards

During a 1971 experimental gravity drawdown of Lake Apopka, unexplained deaths of alligators, fish, and turtles caused concern among area citizens. Concern intensified when *Aeromonas* bacteria were found in the lake, since this species has been implicated in serious human illness. While some workers have suspected *Aeromonas* to be the cause of the 1971 animal kills, conclusive evidence was never found.

Personnel from the Florida Department of Health concluded that the threat of *Aeromonas* to human health is negligible. *Aeromonas* infection in humans is extremely rare and apparently occurs only after the human host has already been weakened by debilitation, disease or injury. They further concluded that the water of Lake Apopka was no more threatening to human health than was water from numerous other lakes in Florida. *Aeromonas* has been found in virtually all Florida lakes that have been tested.

Naegleria, the amoeba responsible for primary amoebic meningoencephalitis in man, was found in Lake Apopka waters in September, 1977 (Wellings, Florida Epidemiological Research Center, personal communication). Epidemiological Research Center personnel plan to use Lake Beauclair and other lakes in a 1978-1980 study of the factors influencing the presence or absence of *Naegleria*. Under current conditions in Lake Apopka, *Naegleria* is not considered a threat to human health (Wellings, personal communication).

As noted in the bacterial section presented earlier, bacterial counts in Lake Apopka generally do not exceed Class III standards. Personnel from the Orange County Pollution Control Department stated in June, 1978, that the waters of Lake Apopka currently present no particular human health hazard.

Table 2.11. Endangered, Threatened, Rare, or Special Concern Species in Oklawaha Chain of Lakes Area.

Common Name	Scientific Name	Designation	Affected by Project[1]	Confirming Source[2]
Short-tailed snake	*Stilosoma extenuatum*	endangered[3,4]	No	FG&FWFC
Wood stork	*Mycteria americana*	endangered[3,5]	Yes	Biological Research Assoc. (BRA) & DER
Lewton polygala	*Polygala lewtonii*	endangered[6]	No	University of Florida
Lake Eustis pupfish	*Cyprinodon variegatus hubbsi*	threatened[3]	Yes	FG&FWFC
Florida gopher frog	*Rana areolata aesopus*	threatened[3,5]	No	FG&FWFC
American alligator	*Allgator mississippiensis*	threatened[3,7]	Yes	FG&FWFC
Gopher turtle	*Gopherus polyphemus*	threatened[3,5]	No	FG&FWFC
Bald eagle	*Haliaetus leucocephalus*	threatened[3,7]	Yes	BRA & DER
Osprey	*Pandion haliaetus*	threatened[3]	Yes	BRA & DER
Florida sandhill crane	*Grus canadensis pratensis*	threatened[3,5]	No	BRA & DER
Sherman's fox squirrel	*Sciurus niger shermani*	threatened[3,5]	No	BRA & DER
Florida black bear	*Ursus americanus floridanus*	threatened[3,5]	No	FG&FWFC
Florida mouse	*Peromyscus floridanus*	threatened[3]	No	BRA & DER
Southeastern shrew	*Sorex longirostris longirostris*	rare[8]	No	FG&FWFC
Big brown bat	*Eptesicus fuscus*	rare[8]	No	Archibald Research Center (ARC)

Table 2.11. (continued)

Common Name	Scientific Name	Designation	Affected by Project[1]	Confirming Source[2]
Southeastern big-eared bat	*Plecotus rafinesquii*	rare[8]	No	ARC
Florida weasel	*Mustela frenata peninsulae*	rare[8]	No	FG&FWFC
Short-tailed hawk	*Buteo brachyurus fuliginosus*	rare[8]	No	BRA & DER
Round-tailed muskrat	*Neofiber alleni*	special concern[8]	Yes	BRA & DER
Southern hairy woodpecker	*Dendrocopus villosus*	special concern[8]	No	BRA & DER

[1] Potentially dependent on Lake Apopka.

[2] Source confirming that the species lives in the project area.

[3] According to Florida Threatened Species List, 15 December, 1977, Technical Advisory Committee on Endangered Species (TACES).

[4] Currently being reviewed by U.S. Fish and Wildlife Service for possible inclusion on the federal list.

[5] Recommended by TACES to be proposed by FG&FWFC to be included in the federal list in the same status category as on the state list.

[6] According to Unofficial List of Florida Endangered and Threatened Species.

[7] Also included on Federal List of Endangered and Threatened Species.

[8] Inventory of Rare and Endangered Biota of Florida. Florida Audubon Society and the Florida Defenders of the Environment, 1977. (Microfiche)

Air Quality

Air quality in the Lake Apopka region, as in all Florida, is measured in relation to ambient* air quality standards. Standards for six major air pollutants are addressed in the Ambient Air Quality Standards for Florida (Section 17-2.05, Florida Administrative Code), which is outlined in Table 2.12. The entire state of Florida is currently within a Class II* air quality category or better and the ambient standards reflect this designation (Arbes, DER, personal communication). Readings in excess of the established limits would indicate an infraction of the ambient air quality standards.

Table 2.12. Florida Department of Environmental Regulation
Ambient Air Quality Standards

Pollutant	Annual	24 hr[1]	8 hr[1]	3 hr[1]	1 hr[1]
SO_2*	60 ug/m^3 0.02 ppm	260 ug/m^3 0.10 ppm		1300 ug/m^3 0.50 ppm	
Particulates* (TSP)	[2]60 ug/m^3	150 ug/m^3			
CO*			10 mg/m^3 9 ppm		40 mg/m^3 35 ppm
Ozone*					160 ug/m^3 0.08 ppm
Hydrocarbons*				[3]160 ug/m^3 0.24 ppm	
NO_2*	100 ug/m^3 0.05 ppm				

ug = micrograms　　mg = milligrams　　ppm = parts per million

1 - not to be exceeded more than once per year
2 - annual geometric mean
3 - 6 a.m. to 9 a.m. only

Source: Section 17-2.05, Florida Administrative Code.

Poor air quality has not been a major problem in East Central Florida. Some industry is located in the Lake Apopka area; however, the most extensive use of land is agricultural. Orlando is the largest urban center in the region, but it supports little industry which would contribute significantly to unacceptable air quality. Due to the large number of automobiles associated with the Orlando urban area, however, extensive emissions from internal combustion engines can be major sources of air pollution. Ozone, which is caused mainly by the action of sunlight on automobile emissions, and hydrocarbons, which result from incomplete fuel combustion and evaporation of gasoline, are definitely problem pollutants. Both of these pollutants are under federal decree for non-attainment of ambient air quality standards in the Orlando area (Collins, DER, personal communication).

Air quality readings for three other pollutants (particulates, SO_2, and NO_2) in the Orlando area are recorded in Table 2.13. These raw data are not indicative of every discrete area within downtown Orlando, but do represent air quality readings for the city as a whole.

Table 2.13. Air Quality Readings for Orlando, Florida.

Pollutant	Monitoring Period	Ambient Standard (ug/m^3)	Recorded Level (ug/m^3)
Particulates	1970-72	60	65.52
	1973		61.10
	1975		53.61
	1976		49.41
	1977		55.34
SO_2	1973	60	2.78-11.22
	1974-75		7.57
NO_2	1975	100	3.69

Source: Florida DER, 1978. Ambient Air Quality.

A reduction in the level of total suspended particulates was clearly evident in the Orlando area from 1970 to 1976. It should be noted that 30 to 45 ug/m^3 of particulates would occur in the air even without additions from local man-made sources (Arbes, DER, personal communication). Orlando only slightly exceeded this background level in 1976. Since then, however, particulate levels have risen continuously and are currently a problem in both Orlando and Orange County. Readings of SO_2 and NO_2 levels were well within the ambient air quality standards for Class II air in 1975 and have remained so since then. Clearly, the Orlando area poses no threat to acceptable air quality for these two pollutants.

Although the Orlando metropolitan area has experienced problems in meeting ambient air quality standards for various pollutants, the same situation does not necessarily apply to the Lake Apopka region. Support of this statement is given by a 1977 study of air quality for three other cities near Lake Apopka. Total suspended particulate levels, which are currently a problem in Orlando, were sampled at these three sites for a fifteen-day period in January 1977. Table 2.14 illustrates the results of this study, and Figure 2.13 graphically portrays the particulate levels for Leesburg and Okahumpka during the monitoring period.

Table 2.14. Air Quality - Particulate Levels (Annual Geometric Mean).

City	Mean Particulate Level (ug/m^3)
Leesburg	24.7
Okahumpka	16.2
Sanford	31.5

Source: LCPD, 1977. Conservation Element (Draft).

Because cities have historically attracted industry, transportation, and other fossil fuel-intensive businesses, the urban environment is typically more polluted than its surrounding hinterlands. Leesburg and Orlando are the largest urban areas within their respective counties and should theoretically produce the highest levels of air pollution. Although Orlando has experienced problems in meeting the standards for some pollutants, the air in Leesburg is of good quality and well above the state average (LCPD, 1977a). It can be assumed from the above data, therefore, that air pollutant levels in the Lake Apopka study area, excepting ozone, fall between these two extremes.

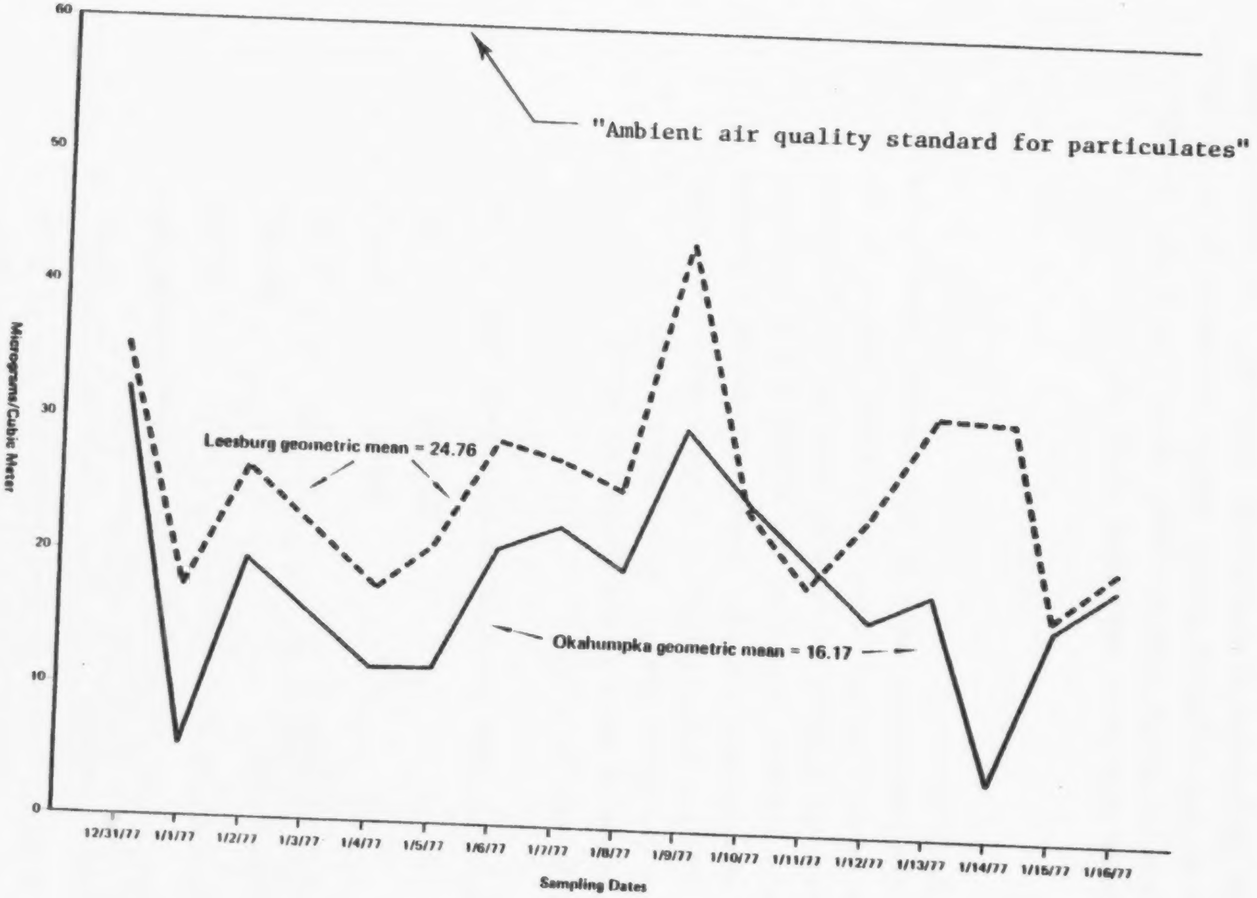

Figure 2.13. Particulate Levels for Leesburg and Okahumpka, Lake County.

Source: LCPD, 1977. Conservation Element (Draft).

No punitive air quality enforcement action is being taken by the Florida DER in the Lake Apopka area at this time. In addition, there have been few violations of the air quality standards and no air pollution episodes in recent history (LCPD, 1977a). In short, the Lake Apopka region experiences relatively clean air.

Land Uses

Existing Land Use

The two predominant types of land use/land cover in the Oklawaha Basin are agriculture and water (Table 2.15). Citrus is the largest single land use in agriculture, comprising nearly 35 percent of the total basin acreage. Row crops and woodlands make up 8 percent of the acreage, with pasture and idle land comprising an additional 16 percent (ECFRPC, 1971). Lakes, streams, lowlands, and marshes constitute 35 percent of the basin acreage. Within the non-agricultural land uses, residential development is the largest category, far exceeding commercial and industrial uses.

Table 2.15. Land Use-Oklawaha River Basin Planning Area, 1970.

	Hectares	Acres
Urban	10,409	25,722
Non-Urban Industrial	1,029	2,543
Agriculture-Citrus	75,714	187,086
Agriculture-Crops	8,461	20,908
Agriculture-Pasture/Idle	33,593	83,008
Agriculture-Woodland	8,344	20,617
Public Holdings	785	1,940
Lowlands	31,243	77,201
Open Water	45,199	111,684
Total	214,777	530,709

Source: ECFRPC, 1971. Upper Oklawaha Comprehensive River Basin Study. East Central Florida Regional Planning Council.

The major concentrations of citrus groves occur along the Lake Wales and Mount Dora Ridges and are interspersed with numerous sinkholes and small lakes. Muck farms to the north of Lake Apopka support the majority of row crop land uses, while forested wetland areas fringe the lake in several places, especially along the northwestern shoreline. North of Lake Dora lies the heaviest concentration of urban areas, including the Golden Triangle of Eustis, Tavares, and Mount Dora. Between Lakes Eustis and Griffin lies a highly diversified area which includes citrus, cropland, pastures, wetlands, and urban centers. Throughout this multiplicity of land uses, agriculture maintains its significance with citrus groves dominating all other land use categories. Figure 2.14 illustrates the present land uses surrounding Lake Apopka.

Projected Land Use

Nearly all acreage that is suitable for citrus production is now in use. The remaining land has unsuitable soils, excessive freeze risks, or is currently being put to a more profitable use. Soils that are suitable for citrus, however, are also usually suitable for residential development (Adley Associates, Inc., 1968). By 1990, therefore, total citrus acreage is expected to decrease due to urban encroachment. Organic row crop farming is expected to undergo little expansion; however, it is not likely to lose ground to urban development as organic soils are not conducive to structural development.

Non-agricultural development is expected to increase by approximately 6557 hectares (16,202 acres) from 1970 to 1990 (Table 2.16). Much of this increase will come from lands that are currently zoned agricultural and could be absorbed at the rate of about 4.4 km^2 (1.7 mi^2) per year (LCPD, 1977c). A significant portion of this growth is expected to occur in a crescent-shaped area from the southwest of Lake Apopka, through Winter Garden and around to the northwest of the city of Apopka (ECFRPC, 1971). The urban areas of Orlando, Leesburg, Tavares, Eustis, and Mount Dora are also expected to expand considerably (Adley Associates, Inc., 1968).

Most of Orlando's past growth has been away from Lake County's citrus groves because cheaper land was available to the east. In effect, the citrus groves acted as barriers to westerly urban sprawl from Orlando

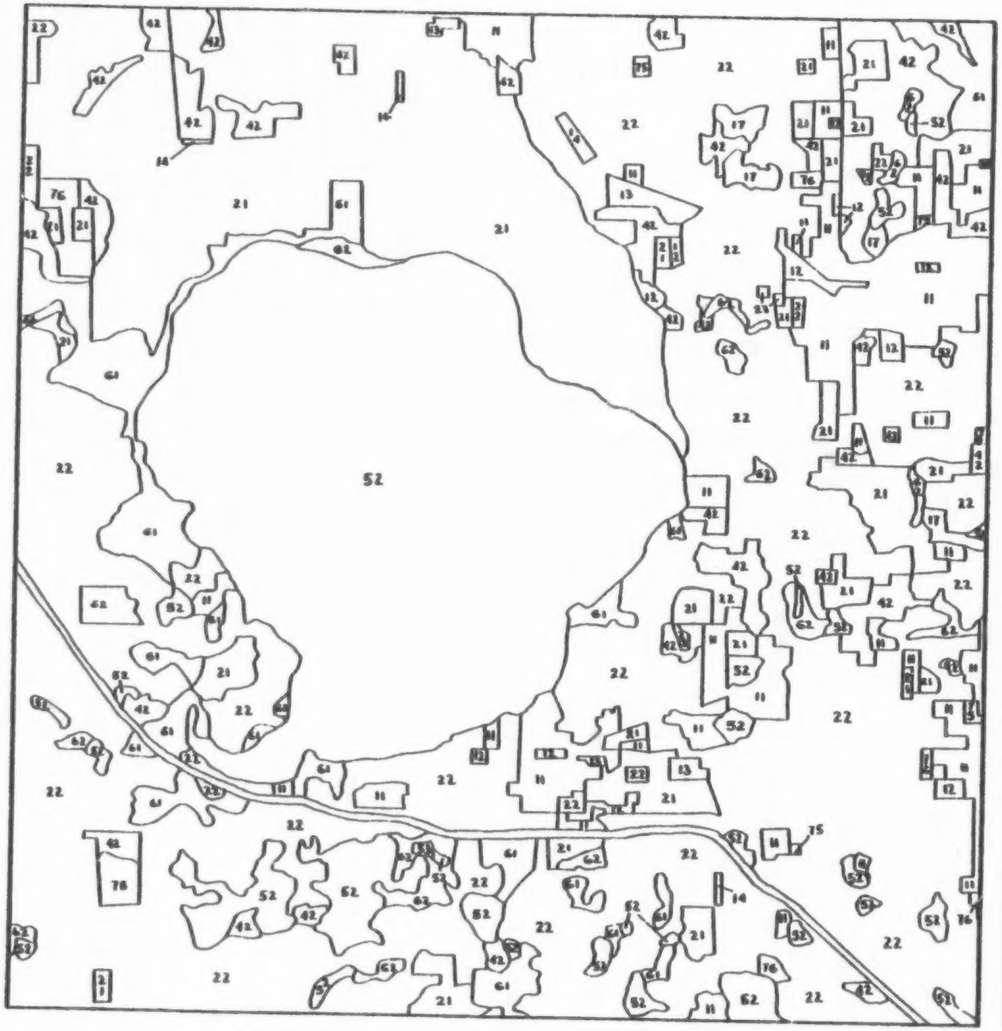

Figure 2.14. Land Use and Land Cover, 1972, Level II Classification.

1 URBAN OR BUILT-UP LAND
11 Residential
12 Commercial and Services
13 Industrial
14 Transportation & Utilities
15 Indus. & Commercial Complexes
16 Mixed Urban or Built-up Land
17 Other Urban or Built-up Land
2 AGRICULTURAL LAND
21 Cropland and Pasture
22 Orchards, Groves, Vineyards, Nurseries, and Ornamental
23 Confined Feeding Operations
24 Other Agricultural Land
3 RANGELAND
31 Herbaceous Rangeland
32 Shrub and Brush Rangeland
33 Mixed Rangeland
4 FOREST LAND
41 Deciduous Forest Land
42 Evergreen Forest Land
43 Mixed Forest Land
5 WATER
51 Streams and Canals
52 Lakes
53 Reservoirs
6 WETLAND
61 Forested Wetland
62 Nonforested Wetland
7 BARREN LAND
71 Dry Salt Flats
72 Beaches
73 Sandy Areas Other than Beaches
74 Bare Exposed Rock
75 Strip Mines, Quarries, and Gravel Pits
76 Transitional Areas

0 1 2 3 4 5 mi
0 1 2 3 4 5 km

Source: U.S. Department of the Interior, Geological Survey, Land Use Series, 1972.

(Adley Associates, Inc. 1968). Apopka and Ocoee, however, have experienced substantial growth associated with Orlando's development.

Table 2.16. Nonagricultural Land Use in Hectares, Oklawaha River Basin Planning Area, 1970-1990.

	1970	1990	Increase	% Increase
Residential	4,212	5,964	1,752	41.6
Industrial	301	514	213	70.8
Commercial	334	1,076	742	222.2
Parks and Recreation	2,439	4,842	2,403	98.5
Public Use	2,079	3,526	1,447	69.6
Total	9,365	15,922	6,557	70.0

Sources: 1964 Aerial Photographs, East Central Florida Regional Planning Council Area. ECFRPC, 1970. Population, Housing, and Employment Update.

To protect Lake County from extremely rapid urban expansion and uncontrolled growth, the County Planning Department has incorporated an Urban Containment Policy, which strives to place development in or around existing urban areas (LCPD, 1977c). This policy contends that leapfrogging and urban sprawl can be prevented without creating an undesirably high-density urban environment. Furthermore, agriculture will be encouraged and protected as a "viable economic use on suitable soils in Lake County" (LCPD, 1977a).

The Lake County Land Use Plan Element includes the following objectives and policies which will influence future land use patterns in the region:

- Agriculture is a major economic resource to the County and must be protected from urban encroachment.
- Lakeshore development shall occur in a manner which will enhance its natural character, avoid damage to indigenous environmental factors and assure an adequate amount of public access to waterfront areas.
- Appropriate setbacks from lake frontages should be required to act as vegetative-nutrient absorption buffers to protect the lake water quality.

-Urban growth should be encouraged in areas which are presently developed as urban centers. This will contain urban sprawl and minimize energy costs.

This urban compact development plan will concentrate future growth in desirable areas and protect the agricultural economic base of the region. In addition, such a plan will provide taxable open space, maintain air and water quality, retain groundwater recharge areas, provide wildlife habitat, and protect environmentally sensitive areas LCPD, 1977c). The result of such a growth policy will be a spatial land use pattern which is compatible with the natural and man-made environment.

Environmentally Sensitive Areas

Certain areas within the Chain of Lakes Basin are not environmentally conducive to development. These sensitive areas attain their highest and best use through the maintenance of ecosystem quality and stability. Wetlands and flood-prone areas form the majority of such areas, the most significant of which are discussed below. According to the Lake County Conservation Element, sensitive areas such as these should be protected.

Dora Canal. This beautiful cypress swamp is contained totally within the Tavares city limits. Lake County has acquired ownership or control of the banks on either side of a major portion of this canal, but some parts of it are still unprotected. The floodplain here does not seem suitable for development, yet mobile home courts exist on the Lake Dora end of the canal. Numerous bird and wildlife species inhabit the canal and add to its unique nature.

Dead River. This short waterway lies approximately one mile northwest of the Dora Canal and connects Lakes Harris and Eustis. Plans were once made to dredge and widen the river to provide high-priced water frontage, but so far it has been preserved primarily in a natural state. Some home development has occurred along the river both in and out of the flood-prone area.

Double Run Swamp. Connecting the northwestern shore of Lake Apopka and the southern edge of Little Lake Harris is a section of forested wetlands. A series of springs originating near Highway 561 forms a small stream which flows for about one mile northwest to Little Lake Harris. The water in this stream is clear and the bottom is visible at depths up to 1.5 m (5 ft). This area serves as a habitat for alligators, turtles, and many birds and is currently undeveloped (LCPD, 1977a). The portion of Double Run Swamp between Lake Apopka and Highway 561 is more of an upland forest and supports birds and water fowl. Numerous other wildlife species associated with forested lands also abound in this area.

Goose Prairie and Emeralda Marsh. North of Lake Eustis between State Roads 44 and 452 a marsh of approximately 263 hectares (650 acres) exists. It serves as a habitat for various species and assimilates nutrients from the surrounding area. An effort to purchase this Goose Prairie marsh under the Environmentally Endangered Lands Program failed. Emeralda Marsh consists of 3926 hectares (9700 acres) of wetlands between Lake Griffin and State Road 452. Although much of this area has been converted to muck farms, the remaining undisturbed marsh is a natural fish hatchery and bird rookery.

Other Areas. In addition to the above areas, several smaller important sites exist within the basin. Haines Creek, which connects Lakes Eustis and Griffin, is bordered by low, swampy ground and is a flood-prone area. Floating Islands is a group of three islands in Lake Griffin which is an important natural asset as a nesting area for numerous species of birds, including Florida Egrets and Herons. Gator Island, Crown Point, Apopka Springs and several other areas along the shoreline of Lake Apopka are sensitive wetland habitats. These areas lie within the flood-prone area and should be managed in accordance with the Floodplain Zoning Principle: "in existing urbanized areas, keep the water from interfering with the people. In all other areas, keep the people from interfering with the water" (LCPD, 1977c).

Population Projections and Characteristics and Economic Forecasts

Population Projections

Lake Apopka lies within Lake and Orange Counties, which means the lake's surrounding population will be affected by trends in both counties. Because the Oklawaha Chain of Lakes lies predominantly within Lake County, however, population and economic trends can be analyzed more accurately by examining Lake County rather than Orange County data. The Orlando Standard Metropolitan Statistical Area (SMSA), although physically close to Lake Apopka, does not represent the population or economic base of the study area. Hence, data for Orange County and the Orlando SMSA would be misleading. Basically, the characteristics and history of Lake County reflect those of the entire Oklawaha Chain of Lakes region (ECFRPC, 1971).

Population growth in the Oklawaha Basin Planning Area (Figure 2.15) has historically been slower than that of Florida as a whole. Also, the influence of a predominantly agricultural economy has concentrated past growth in rural areas. From 1950 to 1970 population growth was rapid, yet still slower than the growth rate for Florida (Table 2.17). The 1970 population of 69,305 for Lake County represents a 20.8 percent increase since 1960 compared to a 37.1 percent increase for the state (ECFRPC, 1973). However, from 1970 to 1974, the statewide growth rate had reduced to approximately the same rate as Lake County (LCPD and King Helie Planning Group, Inc., 1976).

Table 2.17. Populations for Lake County and Florida

Year	Lake Co. Population	% Increase	Florida Pop.	% Increase
1950	36,340	-	2,771,000	-
1960	57,383	57.9	4,951,560	78.7
1970	69,305	20.8	6,790,929	37.1
1974	83,473	20.4	8,248,851	21.5

Source: U.S. Department of Commerce, Bureau of the Census, General Social and Economic Characteristics, Florida.

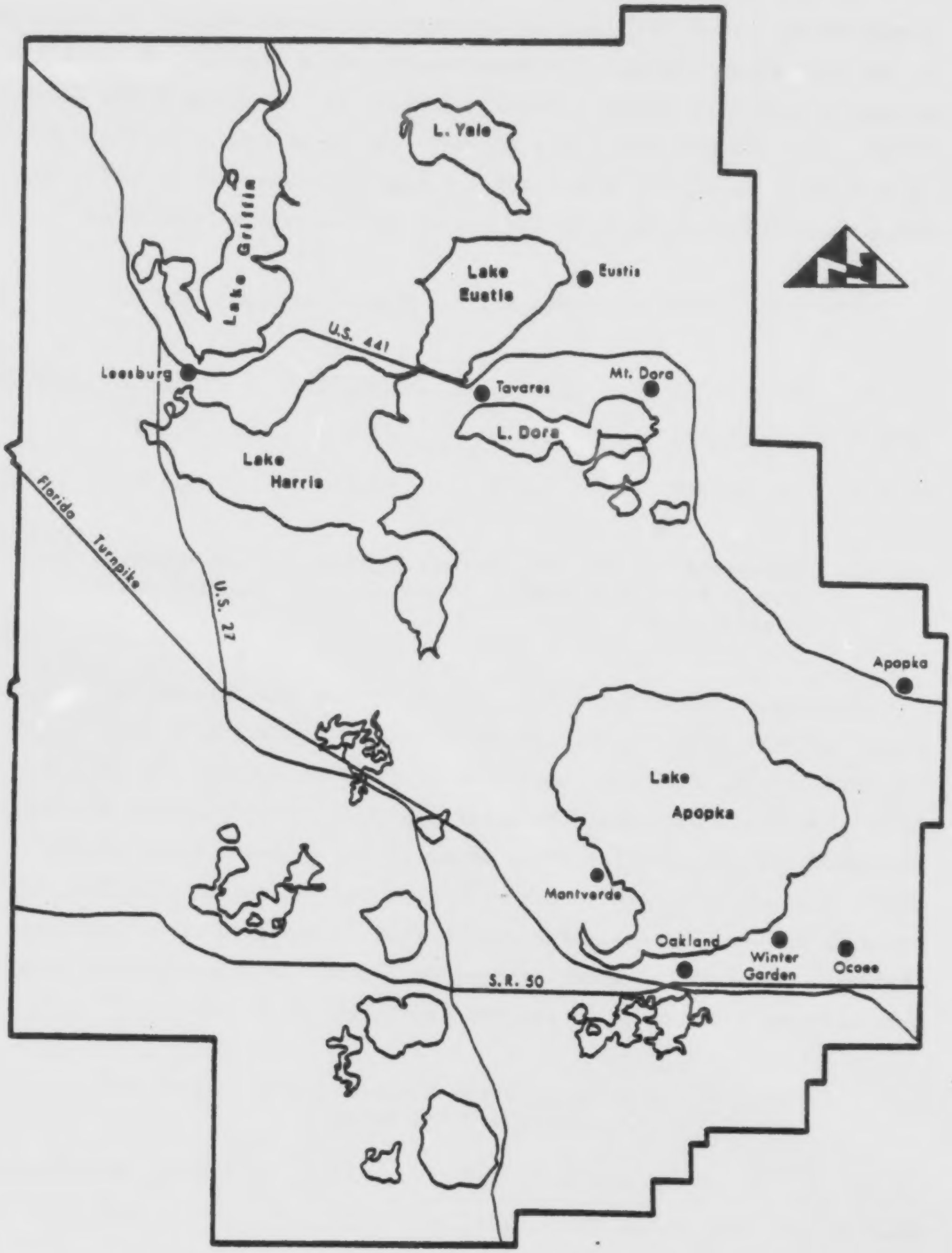
L. Yale
Lake Griffin
Lake Eustis
Eustis
U.S. 441
Leesburg
Tavares
Mt. Dora
L. Dora
Lake Harris
Florida Turnpike
U.S. 27
Apopka
Lake Apopka
Montverde
Oakland
Winter Garden
Ocoee
S.R. 50

Figure 2.15. Oklawaha River Basin Planning Area.

Source: ECFRPC, 1971. Oklawaha Comprehensive River Basin Study. East Central Florida Regional Planning Council.

The most important influence of growth in this part of Florida is in-migration. From 1960 to 1970 net migration accounted for 77.4 percent of the population increase for Lake County, while from 1970 to 1974 it accounted for 102.5 percent (deaths exceeded births--Table 2.18) (LCPD, 1978a). This in-migration rate reflects the large number of retired persons settling in the region and the high percentage of agricultural workers seeking employment in the citrus and vegetable industries.

Table 2.18. Natural Growth and Net Migration, Lake County.

Period	Pop. Increase	Natural Increase	% Total Increase	Net Migration	% Total Increase
1960-70	11,922	2,689	22.6	9,233	77.4
1970-74	14,168	-177	-2.5	14,345	102.5

Sources: University of Florida, Bureau of Economic and Business Research, 1974. Florida Estimates of Population. Florida Statistical Abstract, 1973.

Population projections for Lake County and the Oklawaha Basin are shown in Table 2.19. A definite trend toward urban growth is expected for Lake County, but since the basin is still agriculturally oriented, it will maintain its rural character. Significant population increases are predicted for specific urban areas in the Oklawaha Basin (Table 2.20), but unincorporated areas will grow just as rapidly (ECFRPC, 1971). Overall, the area's population growth rate is expected to be less than statewide and regional growth rates, as Florida in-migrants seek other, more diverse industrial and economic areas of the state.

Table 2.19. Population Projections for Lake County and the Oklawaha River Basin.

	1970	1980	1990	% increase 1970-1990
Lake County	69,305	102,900	131,500	89.8
Oklawaha Basin	96,812	-	172,593	78.3

Sources: Florida Statistical Abstract, 1976. ECFRPC, Population Forecasts.

Table 2.20. Population Projections for Specific Divisions (Urban and Rural) in the Oklawaha Basin.

	1970	1990	% Increase
Apopka	15,403	33,056	114.6
Ocoee	7,466	16,118	115.9
Winter Garden/Oakland	8,729	14,700	68.4
Clermont/Montverde	7,012	12,872	83.6
Leesburg	13,526	30,213	123.4
Mount Dora	8,591	16,750	95.0
Eustis	10,176	17,019	67.2
Tavares	6,348	21,831	243.9

Sources: ECFRPC. Final Count, Advance Report, 1970 Census. Lake and Orange County Aerial Photographs, 1968.

Population Characteristics

A. Age. Due to its high in-migration of retired persons, Lake County has historically supported a concentration of older residents. In 1970, 33.6 percent of Lake County's population was 55 or older, compared to the state proportion of 25.0 percent (ECFRPC, 1973). This skewed age distribution is also reflected in the median age for the county, 31.9 in 1950 compared to 30.9 for Florida. By 1960, median age in Lake County climbed to 34.3 compared to 31.2 for Florida. This trend continued through 1970 and is expected to be a major factor in Lake County's future age structure (LCPD and King Helie, 1976). Population pyramids and population projections by age group are shown in Figure 2.16 and Table 2.21, respectively. A significant decline in the younger age categories is expected by 1990, due to the declining birth rate; however, the elderly proportion of the population will remain high. The trend, therefore, is toward a greater concentration of middle and upper age residents, with a corresponding increase in median age.

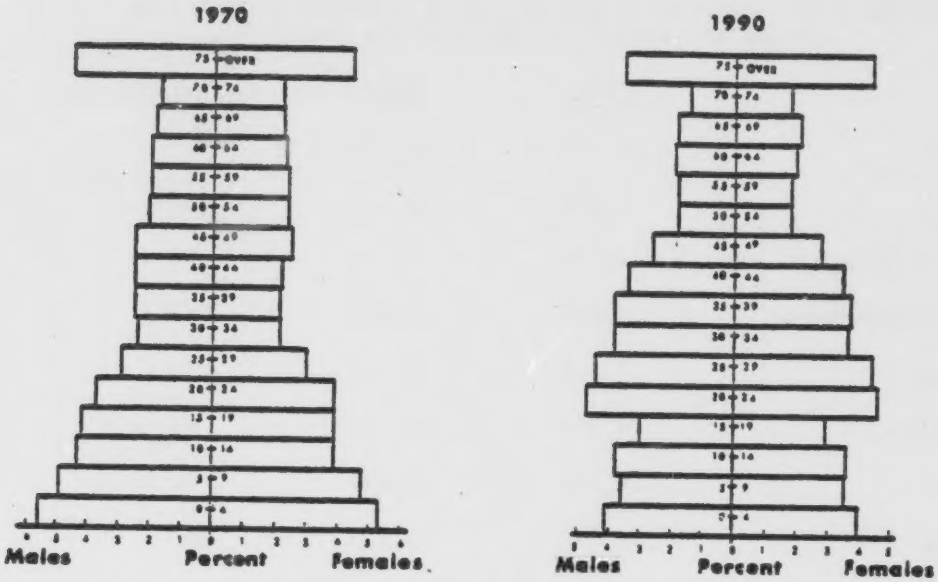

Figure 2.16. Population Pyramids - Oklawaha River Basin Planning Area, 1970-1990.

Source: ECFRPC, 1971. Oklawaha Comprehensive River Basin Study. East Central Florida Regional Planning Council.

Table 2.21. Age Group Population Projections: Oklawaha River Basin Planning Area, 1970-1990.

	1970		1990	
Age Group	Group Total	% Total Pop.	Group Total	% Total Pop.
0-9	20,082	20.7	26,215	15.2
10-19	15,876	16.4	23,175	13.4
20-29	13,122	13.6	31,214	18.1
30-39	8,740	9.0	25,602	14.8
40-49	9,484	9.8	21,416	12.4
50-59	8,771	9.1	12,583	7.3
60-69	8,211	8.5	13,208	7.7
70+	12,526	12.9	19,180	11.1
Total	96,812	100.0	172,593	100.0

Source: ECFRPC, Population Forecasts.

B. Income. Median family income for the Oklawaha Basin has been lower in the past than for Florida as a whole. In 1969, Lake County's median family income of $6,352 was 23.2 percent lower than the statewide figure of $8,267 (ECFRPC, 1973). Distribution of county families by income shows a greater concentration of families in lower income categories than for the state as a whole (Table 2.22). In 1969, 46.9 percent of Lake County's families reported incomes of less than $6,000 compared to 33.9 percent of statewide families.

Table 2.22. Income of Families, Florida and Lake County 1959 and 1969.

	% of Families			
	Florida		Lake County	
Income Range	1959	1969	1959	1969
Less than $1000	14.1	3.0	8.1	2.7
1000 to 1999	13.4	4.1	14.1	6.4
2000 to 2999	12.7	5.8	18.0	9.8
3000 to 3999	12.0	6.7	14.5	8.8
4000 to 4999	10.3	6.9	11.4	10.0
5000 to 5999	9.4	7.4	9.6	9.2
6000 to 6999	7.2	7.2	6.3	8.6
7000 to 7999	12.0	20.1	10.1	18.2
10,000 to 14,999	----	22.1	4.8	15.9
15,000 to 24,999	8.8[1]	12.4	2.1	7.9
25,000 or more	----	4.4	1.0	2.5

[1] Includes all families earning $10,000 or more.

Source: U.S. Department of Commerce, Bureau of the Census

This low median family income reflects the predominantly agricultural character of the area's economy and the lack of a diversified industrial and commercial economic base (LCPD and King Helie, 1976). The high proportion of elderly residents who rely on pensions and social security benefits also contributes to this lower income value. Their low income, however, does not necessarily indicate a lower standard of living. Many of these retired, elderly families enjoy fewer family expenses and have paid in full their home mortgages.

In recent years, Lake County has experienced a relative increase in median family income. The $6352 median family income of 1969 jumped to $7280 by 1972, representing the second greatest increase in family income for the East Central Florida Region (ECFRPC, 1973). By 1975 Lake County closed to within 10% of the statewide figure, continuing the trend of decreasing differences between state and Lake County median family incomes (LCPD and King Helie, 1976).

C. Housing. The types of housing in Lake County are directly related to income and age groups. Population per household decreased from 3.02 in 1960 to 2.81 in 1974, reflecting a high influx of retired persons with small families (ECFRPC, 1973). This trend has resulted in a retirement community characterized by mobile homes and single-family dwelling units. The most recent trend has been especially skewed towards mobile homes. Of the total 1976 Lake County building permits for residential dwellings, 60 percent were for mobile homes, 37 percent for single-family dwellings, and only 2 percent for multi-family units (ECFRPC, 1977). Mobile homes have increased so sharply in unincorporated areas since 1970 that they may eventually outnumber single-family dwellings.

Housing units for the entire county reflect a significant concentration in single-family homes, which accounted for 77.0 percent of all housing units in 1970. Mobile homes comprised 12.3 percent and multi-family dwellings made up 10.7 percent of county dwelling units (ECFRPC, 1973). The percentage of mobile homes in the county was twice that for the entire state, while the percentage of multi-family dwelling units was the lowest in East Central Florida. Clearly, single-family dwellings are the preferred living units for this area; however, the shift towards mobile homes continues to increase.

The value of housing units remains somewhat below the state average, although the median values for Lake County and Florida have been drawing closer together. Table 2.23 illustrates housing values for the county and state in 1970, while enumerating the proportion of housing units within each division.

Table 2.23. Housing Values, 1970. Lake County and Florida.

Value Range	% of Lake Co. Housing	% of Florida Housing
Less than $5000	9.3	5.2
5000 - 9999	26.8	17.6
10,000-14,999	27.7	26.9
15,000-19,999	16.8	20.9
20,000-24,999	7.9	11.6
25,000-34,999	6.8	10.2
35,000 and over	4.7	7.6

Median value Lake County housing - $12,513
Median value State of Florida housing - $15,100

Source: University of Florida Census Access Program, Computer Printouts of 1970 Census Tapes.

Economic Base

Economic development in the Oklawaha Basin from 1958 to 1967 was relatively modest compared to some of the more urbanized areas in Central Florida. Agriculture and manufacturing form the primary economic base, because they produce the key exports which bring outside capital into the region. Agriculture is the more important of these two industries and supports much of the manufacturing industry through citrus packing and processing plants.

A. Agriculture. Citrus and vegetables are the major crops of the region, but citrus has, by far, the highest crop value. Lake County has been the second largest producer of citrus crops in Florida for at least the past eight years (ECFRPC, 1977). In 1976, Lake County had approximately 51,000 hectares (126,000 acres) planted in citrus, with a majority of this on the Lake Wales Ridge, and supplied 16.2 percent of the state's citrus crop. Vegetable production is much less prominent; however, it complements citrus production and yields high returns on the muck farms north of Lake Apopka.

Agricultural crops for Lake County are valued at $85 million annually (LCPD, 1977a). In addition, approximately 23,000 persons, or 64 percent of the work force, are employed in agriculture and related occupations such as packing houses, processing plants, and fertilizer plants. Accordingly, a substantial percentage of Lake County's income is agriculturally based. In 1969, agriculture accounted for 40.1 percent of total income in Lake County (Table 2.24) compared to 4.5 percent for Florida. Subsequent years have shown a considerable decrease in this proportion; however, this is in conformance with national trends. As freezes occur and urban pressures increase, citrus groves are taken out of production and replaced with residential developments. The area's economy is gradually diversifying, yet agriculture remains a prominent source of income. In 1975, farm earnings for Lake County exceeded 26 percent of total earnings compared to 4 percent for Florida.

Table 2.24. Lake County Farm Income as Percent of Total Labor and Proprietors' Income.[1]

	Farm Income (Thousands)	% of Total
1965	$24,596	26.7%
1966	25,131	26.4
1967	38,482	32.5
1968	45,337	33.7
1969	67,519	40.1
1970	61,245	35.4
1971	64,517	34.4
1972	68,313	32.6
1973	68,265	28.7
1974	60,445	23.3
1975	75,721	26.4

[1] By place of work.

Source: Regional Economics Information System, U.S. Bureau of Economic Analysis.

B. Non-Agricultural Industries. Industrial development in Lake County is nearly at a standstill, with non-agricultural employment increasing only 1.3 percent between 1975 and 1976 (ECFRPC, 1977). There is no strong urge to attract new industry at this time either by the retired residents or the agricultural companies. Residents feel that support facilities in the county are insufficient to handle the externalities of new industry. Eustis and Mt. Dora, for example, have moratoriums on sewer hook-ups until the existing sewer system can be expanded (ECFRPC, 1977). Agricultural industries do not want new industry introduced at the expense of valuable agricultural land.

Manufacturing and mining were among the most rapidly expanding industries in the county from 1967 to 1974. These industries suffered setbacks from 1974 to 1977, however, and lost 13 establishments and 1111 employees (LCPD and King Helie, 1976). Nevertheless, they still provide an important source of income for the county. Food products and packing and shipping of fresh fruit account for 23 percent of the manufacturing establishments and complement the extensive agricultural industry (LCPD, 1978a).

The public services sector of the economy gained in importance from 1960 to 1973, with a 53 percent increase in employment from 1970 to 1973. The recession of 1973 reversed this trend, however, and in 1976 this industry suffered a 13 percent loss in employment (LCPD, 1978a). Construction activity increased steadily until 1973 when the recession stifled the building trade. This industry has only recently experienced a gradual recovery. Government employment weathered past economic fluctuations, and continues to comprise a substantial segment of the working force. Overall, Lake County's occupational breakdown (Table 2.25) does not significantly differ from the state breakdown, except for the importance of agriculture.

Table 2.25. Lake Co. Earnings by Broad Industrial Sector (% of Total Earnings) 1975.

Activity	%
Farm Earnings	26.40
Total Non-Farm	73.60
Government	12.70
Private	60.90
Manufacturing	7.78
Mining	0.38
Contract Construction	6.06
Transportation, Communication, and Public Utilities	6.03
Trade	20.02
Finance, Insurance, and Real Estate	4.34
Services	14.24
Other	2.05

Source: Regional Economics Information System, U.S. Bureau of Economic Analysis.

C. Unemployment. Unemployment rates in the area were fairly stable until the recession of 1973 (Table 2.26). Since then unemployment has risen steadily from 4.5 percent in 1974 to approximately 9 percent in 1977 (LCPD, 1978a). The highest unemployment has consistently been recorded for blacks and females. While minority populations comprised only 15 percent of the Lake County population in 1977, minority unemployment accounted for 34 percent of total unemployed persons (LCPD, 1978a).

Table 2.26. Unemployment Trends, Lake County.

	1962	1965	1970	1973	1976
Labor Force	18,900	19,900	24,780	29,380	31,700
Total Unemployed	650	500	720	680	2900
% Unemployed	3.4	2.5	2.9	2.3	9.1

Source: Florida Department of Commerce, Division of Employment Security. Research and Statistics.

Economic Projections

Agriculture has historically been the primary economic base of the area. In 1960, 6.8 percent of the county population was directly employed full-time in agriculture. This proportion declined steadily through 1976 and is expected to reach 3.5 percent by 1980. After 1980, this proportion should remain constant at 3.0 percent (LCPD and King Helie, 1976). This trend is caused by increasing urbanization in the county and mechanization of agriculture. When processing and shipping aspects are considered in conjunction with actual field work, however, agriculture generates the greatest number of employees in the county (LCPD and King Helie, 1976). There is no doubt, therefore, that agriculture will remain the primary economic base of the region.

Non-agricultural employment will increase as agriculture decreases in the basin. From 1970 to 1990 service and government related industries are expected to increase the most, as much as 400 percent and 134 percent, respectively (ECFRPC, 1971). Trade and manufacturing industries will continue to play a major role in the economy and will grow in response to the demands of an increasing population. Other agriculture-related businesses such as the foliage industry will also expand. The city of Apopka remains the "foliage capital of the world"; over 200 nurseries have been established in the area since January, 1975 (ECFRPC, 1977). These shifts in employment structure will provide greater diversity and stability to the area's economy.

Cultural Features

Transportation

The primary transportation system of the Oklawaha Basin consists of highways, railways, and airports and connects the basin to outside economic interests while providing inter-basin transportation.

The roadway network consists of three principal arterials, several minor arterials and numerous connector and local routes (see Figure 2.15). The most important roads are the Florida Turnpike, U.S. 27, State Road 50, and U.S. 441. The Florida Turnpike toll road travels in a southeasterly direction from I-75 west of Leesburg to the tip of Lake Apopka near Gourd Neck and Oakland. From there this four-lane, limited-access highway veers to the south of Orlando. There are only two Turnpike interchanges in the basin, one at State Road 19 and another near Winter Garden; therefore, the turnpike carries very little local traffic, except for some commuters to Orlando. No traffic volume capacity problems are foreseen for this highway and no changes in its layout are planned by 1990 (LCPD, 1977b).

The second principal arterial, U.S. 27, is a four-lane facility without controlled access. U.S. 27 extends north of the region to Ocala and Gainesville and south past Walt Disney World. Because of Disney World, traffic flow on this roadway has increased dramatically in recent years (LCPD, 1978a). U.S. 27 is classified as a major arterial for 1990 and will be upgraded as necessary to handle future traffic volumes.

State Road 50 runs east-west through Lake County, approaches the southern edge of Lake Apopka and continues on to downtown Orlando. This highway suffers from a basic conflict in that it serves local traffic and businesses as well as through traffic. Sections of the road are currently being four-laned to alleviate this problem.

U.S. 441 has been classified as both a major and minor arterial. Commercial "strip" development along this highway has resulted in numerous traffic problems which are expected to intensify. U.S. 441 travels east-west through Leesburg, Tavares, and Mount Dora before turning south towards Zellwood and Apopka. Because of this urban corridor route, conflicts between local and through traffic are unavoidable. Alternative corridors for this highway may be impossible because of the many lakes bordering the roadside. Therefore, other solutions must be found to mitigate these conflicts (LCPD, 1977b).

Public and private airport facilities abound in the area, although the closest regularly scheduled commercial flights are in Orlando and Ocala. Lake County has accepted the Florida Aviation System Plan for East Central Florida. This study designated the Leesburg Municipal Airport as the major airport in Lake County and concluded that airports in the area have sufficient capacity to accomodate short-range projected air travel demand (LCPD, 1977b).

Rail service is provided by the Seaboard Coast Line Railroad. Although no passenger service is available, piggyback and carload freight is common in almost all urban areas. Greyhoud Bus Lines provides passenger service for the region and handles small freight service between the major urban centers. Numerous trucking companies also have offices in the area. Trucks transport a significant portion of the agricultural products of the basin and depend on a good highway network. Overnight deliveries to Atlanta are guaranteed, while shipments to New York or Chicago require three to four days (LCPD, 1978a).

Recreation

Outdoor recreational demand has risen sharply in the U.S. since 1950. Population growth, improved transportation, increased leisure time, higher standards of living and longer life expectancy have all contributed to the increase (Florida DNR, 1976). This national trend is reflected in the Oklawaha River Basin.

The large elderly population of the basin contributes even more to recreational demand, because retirees have more leisure time for participation in outdoor recreation. Also, the project area has a climate and physical environment well suited to outdoor recreation. Most recreationists desire water-based recreation sites where fishing, swimming, and boating can be pursued (Florida DNR, 1970). The Oklawaha Basin, with its numerous lakes, rivers, and streams, fulfills this requirement.

The Ocala National Forest to the north of the area provides recreational opportunities on a regional basis, while smaller facilities along the basin lakes serve local needs. Lake Griffin State Park, a 171 hectare (423 acre) resource, offers camping, picnicking, boating, and nature study. Lake Jem Park and Summerall Park provide picnic facilities and boat ramps. Lake Jem is a 4 hectare (10 acre) wooded parcel adjacent to the Apopka-Beauclair Canal; Summerall Park is on the Dora Canal. Tavares Recreational Park on Lake Eustis has picnic facilities and a boat ramp, and there are two other county boat ramps on the lake. Orange County supports two parks which offer a variety of facilities. Magnolia Park is located on the eastern shore of Lake Apopka, and Trimble Park rests on a peninsula separating Lakes Beauclair and Carlton. Numerous municipal and private facilities in the area provide further recreational opportunities.

Past recreation in the basin has centered directly around the lakes. A survey of recreationists in East Central Florida in the early 1970's showed that the majority of respondents participated in freshwater fishing (Table 2.27). This breakdown was also representative of the Oklawaha Basin prior to the mid-1960's, but by the 1970's, boating had replaced fishing as the major activity on basin lakes (ECFRPC, 1971). This shift occurred because of the drastically reduced fishing opportunities on the lakes.

Table 2.27. Recreation Participation Survey, East Central Florida.

Activity	% Respondents Participating
Fishing	67
Pool Swimming	33
Park Visitation	33
Lake Swimming	25
Boating	25

Source: ECFRPC, 1973. Open Space and Recreation Plan.

Fishing in the chain of lakes peaked in the early 1950's and was the major recreational benefit derived from Lake Apopka. By 1956, 71 fish camps were established on basin lakes, with 21 of these on Lake

Apopka (ECFRPC, 1971). Excellent bass fishing attracted nationwide attention, and the fish camps were comprised of investments exceeding one million dollars (Ledebur, 1967).

During the 1960's, fishing pressure on the lakes decreased significantly. By 1965 only nine fish camps remained on Lake Apopka and had average gross incomes of about $11,000, compared to $37,000 in 1951 (Ledebur, 1967). Population during the sixties increased 20.8 percent, yet the number of fishing licenses issued in Lake County dropped by 11.0 percent, with a majority of this decrease occurring from 1967 to 1970 (ECFRPC, 1971). Even though fishing remained a major recreational activity in East Central Florida, on the chain of lakes, especially Apopka, it was no longer a significant leisure activity.

Only four fish camps remained on Lake Apopka by 1976, down 76 percent since 1961. It was once possible to see over 200 boats per day on Lake Apopka. Today, few boats use the lake. The remaining fish camps are dependent on cottage rentals for income, and "there is virtually no sportfishing" on Lake Apopka (LCPD, 1977a). Although the other lakes support game fish of varying populations, fishing in Lake Apopka as a form of recreation is negligible.

Predicting future recreational activity on the lakes is difficult. As population, income, and leisure time increase, recreational demand in the basin continues to grow. However, poor water quality has resulted in fewer recreational opportunities. Fishing and swimming have actually decreased in the past decade, and lakeside parks are currently underutilized. A basic conflict exists, therefore, in that demand is increasing while opportunities decrease. Quality, water-based recreation sites so desired by outdoor recreationists are no longer available in this area. Consequently, recreationists must travel to other areas which offer better recreation sites. Future recreational participation in the area, therefore, will depend greatly on the water quality of available resources.

Tourism

The Oklawaha Basin has never attracted the "typical" Florida tourist. Most tourists visiting the region are older than average, inclined toward seasonality, and interested in tranquility (ECFRPC, 1971). When the lakes supported healthy sportfisheries, many of the tourists were fishermen. Since the decline in sportfishing, the area has attracted visitors seeking the relaxation associated with semi-retirement.

Many basin tourists stay for the season in rental units and second homes, or visit with friends and relatives. During 1967-1968, 56 percent of the tourists stayed with friends or rented homes, and another 9 percent stayed at their own second homes (ECFRPC, 1971). Consequently, there is less need for tourist-oriented hotels, motels, and restaurants. The number of such establishments has remained rather stable since the mid-1950's, although food service businesses have prospered along the major highways.

Many Florida tourists pass through this region on their way to Disney World, but there is really no tourist-based economy of major significance. The effects of Disney World on the basin have been minimal, and the area "never did get much of a Disney spin-off in relation to tourism" (ECFRPC, 1977). At this time, the rural, agricultural character of the basin is not conducive to a major tourist industry.

Historical/Archeological Resources

The Florida State Historic Preservation Officer was contacted to determine what historical and archeological artifacts of National Register potential would be affected by the proposed project. A review of the Florida Master Site File indicated that no sites have been recorded; however, there has never been a comprehensive survey for such sites conducted in the area. The State Historic Preservation Officer has recommended that the area be "subjected to a professional archeological and historical survey." The survey would identify properties that are potential listings for the National Register of Historic Places.

If any sites or artifacts are discovered in the project area they will most likely be of Indian origin. Lake County has numerous Indian archeological sites, including several sites south of Lake Harris. The Preservation Officer feels there is a possibility that similar artifacts may be discovered in the project area. Table 2.28 lists those historical and archeological sites in Lake County which have been identified near the shores of Lake Apopka or downstream lakes. These sites are not presently included in the National Register of Historic Places.

Table 2.28. Historical/Archeological Sites Located Near Project Area.

Site Name	Nearby Waterbody	Type Site
Fort Mason Mound	Lake Yale	Mound
Barclay's	Little Lake Harris	Mound
no name	Lake Yale	Mound
Mound A Lake Eustis	Lake Eustis	Mound
Mound B Lake Eustis	Lake Eustis	Mound
Tavares Mound	Lake Dora	Mound
Small Mound Near Tavares	Lake Dora	Mound
Mound Near Old Okahumpka	Lake Denham	Mound
Pine Island	Lake Apopka	Mound
West Apopka	Lake Apopka	Mound
Astatula Beach	Little Lake Harris	Dredged Sherds
Bozeman Mound and Village	Haines Creek	Mound and Village
Treasure Island	Lake Griffin	Midden
Picciola Island Grove	Lake Griffin	Mounds
Stivender House	Lake Harris	Building
Donnelly House	Lake Dora	Building
Horseshoe Island	Lake Harris	Sherd and Flint Area

Source: Florida Department of State (through Lake County Planning Department), 1977.

Other Programs in the Area

Various state and federal agencies in the Orange and Lake County area have been contacted regarding ongoing or planned actions which could be affected by or could affect the restoration of Lake Apopka. Many of FG&FWFC's continuing studies focus on Lake Griffin, which is designated as a Fish Management Area. These include bass tagging efforts, fish population studies, and studies of the movement of pan fishes. The FG&FWFC also conducts creel surveys or interviews with fishermen to determine the degree of success being experienced by fishermen on the lake. Included in the surveys are the number of fish caught and length and weight of these fish. These surveys are carried out in alternate years, first on Lakes Eustis and Dora and then on Lakes Griffin and Harris. Data on Lakes Griffin and Harris have been collected for twelve years.

Another FG&FWFC monitoring project involves follow-up studies to the Lake Carlton drawdown of 1977-78. This five-year limnological program will end in July, 1980.

Sunshine bass, a fast-growing hybrid, are stocked by the FG&FWFC in all the lakes of the Oklawaha Chain except Apopka. The bass are stocked at a density of 25 fish per hectare of water. Follow-up studies have focused on what the bass are eating. The regional FG&FWFC office has also placed fish attractors in some of the lakes of the chain, specifically Lakes Griffin, Carlton, and Yale.

There are also some short-term FG&FWFC experiments involving the planting of *Panicum* sp., *Vallisneria* sp., *Nuphar* sp., and other aquatic plants in the shallow zones of the Chain of Lakes. These plants are then sprayed with hormones to determine the growth changes caused by the addition of hormones.

The Lake Improvement Association, working through the Lake County Board of County Commissioners, conducts a program to haul seine the rough fish from the Oklawaha Chain of Lakes. This program is supported by a special $1 addition to local fishing license fees. Assisted by the FG&FWFC, the Lake Improvement Association carries out this program on a yearly schedule from Lake Beauclair downstream. This schedule could be adjusted if the restoration makes it necessary.

The St. Johns River Water Management District has been using a computer model to simulate storm conditions and gather information on runoff and other factors important to maintaining flood control. This work has emphasized conditions in Lake Griffin, but is being expanded into the other lakes.

The SJRWMD is also responsible for maintaining safe conditions on all structures in the district. In light of this responsibility, there may be routine maintenance work required on the various water control structures and channels during the Lake Apopka restoration project.

The Institute of Food and Agricultural Sciences (IFAS) of the University of Florida maintains an experimental farm adjacent to Lake Apopka. At this farm, scientists are investigating production problems with vegetable and field crops. IFAS is also experimenting with rates of nutrient uptake by cattails and other vegetation. These programs utilize water that is drained from area farms rather than lake water.

The effect of the selected restoration technique upon any of the above mentioned programs will be discussed in the section entitled Impacts of Proposed Alternative and Mitigative Steps for Identified Adverse Impacts.

SECTION 3

ALTERNATIVES AND THEIR EFFECTS

No Action

The extensive nutrient abatement programs instituted for Lake Apopka in the 1970's might suggest some optimism for an unaided return to pre-1947 conditions in the lake. However, this optimism is tempered by an analysis of nutrient budgets for Lake Apopka and by a consideration of the lake's present ecosystem.

One nutrient budget for Lake Apopka was prepared by DPC in 1972, prior to any significant nutrient abatement efforts. At that time, inputs of nitrogen and phosphorus to the lake from all sources were estimated to exceed outputs by 1.3 times and 5 times, respectively. After completion of nutrient abatement programs, inputs of nitrogen should approximately equal outputs, but inputs of phosphorus will still exceed outputs by approximately 3.5 times (using DPC's estimates and calculations from the Water Quality Section). Another pre-abatement nutrient budget for Lake Apopka was prepared in 1973-74 as part of the National Eutrophication Survey done by EPA. In this budget, estimated inputs of nitrogen and phosphorus exceeded outputs by 1.2 times and 2 times, respectively. After abatement, inputs and outputs of nitrogen will be approximately equal, but inputs of phosphorus will exceed outputs by approximately 1.1 times. These two budgets relied on coarse approximations, but both suggest that Lake Apopka's ecosystem will be exposed to a net input of phosphorus, even after the completion of nutrient abatement programs.

As the lake's ecosystem is currently structured, a significant amount of this excess phosphorus is channeled into perpetually blooming populations of phytoplankton. In addition, even after nutrient abatement programs have been instituted, recovery of a lake may be delayed by the release of phosphorus from bottom sediments into the water (Cooke et al, 1977). "Lake Apopka sediment has a low capacity to absorb added phosphate, and mixing of unconsolidated sediment with overlying water acts as a source rather than a sink for aqueous phosphorus" (Fox et al, 1977). All this suggests that algal blooms and the corresponding accumulation of unconsolidated organic sediments would persist in Lake Apopka.

A key factor retarding any tendency for Lake Apopka to spontaneously return to its pre-1947 state is the presence of unconsolidated sediments over most of the lake bottom. The macrophytes, sport fish, and benthic fauna of the lake would all continue to be adversely affected by these sediments. Any improvement in water quality resulting from the nutrient abatement programs would be at least periodically compromised by wind- and motorboat-induced suspension of bottom sediments. Selection of the no action alternative would likely result in no significant changes in Lake Apopka for some time. The lake would probably remain a resource of little economic and aesthetic value.

Enhanced Fluctuation

A contributing factor to the increasing degradation of Florida lakes has been the water level stabilization effort by flood control districts and other agencies (Fox, Brezonik, and Keirn, 1977). Unregulated lakes have withstood abuse better than regulated lakes. The organisms composing lake ecosystems in Florida have evolved under, and therefore are adapted to, periodic and sometimes extreme fluctuations of water levels.

The importance of a periodic natural lowering (drawdown) of the water level of a lake is multi-faceted. Unconsolidated bottom sediments exposed to air and direct sunlight will dry and compact, thus reversing the negative effects of unconsolidated sediments. Compacted sediments can provide suitable substrates for expansion of macrophyte populations, for game fish spawning, and for a diverse assemblage of benthic invertebrates (Fox, Brezonik, and Keirn, 1977; FG&FWFC, 1974). Natural drawdown also concentrates rough fish and allows predators easier access to them, thereby providing a periodic check to expanding rough fish populations.

The surface elevation of Lake Apopka is currently maintained between 20.3 and 20.6 m (66.5 and 67.5 ft) msl (Southwest Florida Water Management District, 1976), and the lake would seem to be a likely candidate for enhanced fluctuation. The presently allowed 0.3 m (1.0 ft) of fluctuation is insufficient to produce any significant exposure of bottom sediments, and no compaction occurs.

The degree of fluctuation in Lake Apopka could be easily increased since the sill depth of the Apopka-Beauclair Canal is approximately 19.6 m (64 ft). A periodic drawdown to 19.6 m would expose a maximum of 17% of Lake Apopka's bottom (Bruderly, 1977), and such an exposure could result in a significant lakeward expansion of the vegetated littoral zone. However, this expansion would likely be temporary. When the lake refilled, this aquatic vegetation would be covered by an additional layer of turbid, phytoplankton-rich water. The resultant intense shading would probably kill much of the vegetation in the littoral zone.

Even with 17% bottom exposure, at least 10,400 hectares of the lake would still be covered with a deep layer of unconsolidated sediments. When the lake refilled, this material would almost certainly be distributed over the recently dried bottom, thereby counteracting the benefits of consolidation.

Thus, enhanced fluctuation, although a good maintenance tool, is not a promising restoration technique for Lake Apopka. Temporary improvements in the littoral zone during each low-water period would be mostly negated upon refill, and improvement of the lake's degraded condition could not be expected for many years.

Chemical Sedimentation

Chemical sedimentation involves the addition of specific chemicals to lake water in order to change the form of a nutrient, making it unavailable for use by macrophytes and algae. Phosphorus is the preferred target because it is the least abundant nutrient in most U.S. waters that can be chemically treated; hence, there is a greater probability of successfully reducing its concentration to an amount small enough to be growth-limiting. Studies in Lake Apopka to determine the growth-limiting factor (algal assays*) indicate that the limiting factor* alternates between phosphorus and nitrogen with time of the year and with sampling site within the lake (EPA, 1977).

The chemical additive used in this restoration technique usually contains a metal which combines with phosphorus in the water to form a compound that settles out of the water to the lake bottom. Chemicals commonly used include alum (aluminum sulfate), sodium aluminate, fly ash and zirconium. Depending upon the method used, chemical sedimentation can remove color, turbidity, algae, bacteria, viruses and some dissolved organic compounds as well as phosphorus. Consequently, this restoration technique has been highly praised for its production of extremely clear water.

Cost estimates for chemical sedimentation vary greatly, depending upon the degree of treatment and whether the chemical is applied to the lake itself of to lake water in external basins. Methods achieving best results require removal of the water to sedimentation basins for treatment but have costs approaching those of municipal waste treatment, \$0.10-0.20/3.8 m^3 (Maloney, 1976). For Lake Apopka, with 182.1 million m^3 of water, the cost of this treatment would be between \$5 million and \$10 million. In 1971, representatives of Dow Chemical Company, together with the Orange County Pollution Control Department, calculated the cost of in-lake processing of Lake Apopka water. Their estimate, corrected to the 1978 cost index (U.S. Department of Commerce, 1978), was \$3.3 million excluding pumping costs (DPC, 1971).

Although chemical sedimentation is very effective in clearing water, neither the external nor the internal technique restores the lake bottom. In fact, in-lake sedimentation of phosphorus and suspended solids produces additional flocculent muck that would only serve to aggravate problems already existing in Lake Apopka. In addition, this type of treatment is temporary. Although the phosphorus is removed from the water, the animals, plants, and sediments release additional phosphorus to the water after treatment. In one variation of the chemical sedimentation technique a "blanket" of the chemical additive is applied to the lake bottom to prevent transfer of phosphorus from the sediments to the water. While this technique extends the life of chemical sedimentation restoration in deeper northern lakes, Lake Apopka is so shallow that wind and motorboat activity would easily cause enough agitation to disrupt the protective "blanket."

Another consideration in choosing a restoration technique is the effect of the process upon the lake's ecosystem. The effects of flocculent sediment upon living organisms in Lake Apopka have been discussed in the section entitled Existing Conditions - Biology. Certain chemicals used in sedimentation have "severe detrimental effects" upon some fish and some zooplankton (Peterson, et al, 1974). Sargent (1976) states that "there is some evidence of possible harmful, long-range effects" due to some sedimentation chemicals now used on lake ecosystems. Generally, the long-term effects of various in-lake chemical sedimentation techniques upon lake ecosystems are not well known.

The effectiveness of chemical sedimentation as a method of lake restoration depends entirely upon the type of lake being considered and the variation of the technique used. In general these techniques are reserved for small lakes (500 hectares) as a temporary solution to nuisance algae problems until long-range solutions can be implemented.

Dredging

The primary purpose of dredging is to remove nutrient-rich sediments, thus preventing nutrient recycling. In addition, dredging deepens the lake allowing increased recreational uses. In northern lakes this deepening allows the lake to become stratified with regard to water temperature. The nutrients from the remaining sediments are trapped in the cold water layer at the bottom and cannot reach the upper layer of warm water where photosynthesis occurs, thus limiting the amount of nutrients available for phytoplankton growth. This nutrient-restricting benefit does not occur in shallow, subtropical lakes due to the relatively limited temperature range of the water and the mixing caused by wind action.

While bottom sediments act as a source of nutrients, they also act as a nutrient sump. Nutrients are in a balanced equilibrium between the sediments and the water. Dredging may expose coarse, nutrient-poor sediments which have a much lower nutrient absorptive capacity, weakening the ability of the lake to cope with new nutrient inputs (Sargent, 1976). However, Fox, Brezonik and Keirn (1977) indicated that the muck of Lake Apopka is saturated with nutrients and that any agitation releases, rather than stores, phosphorus and nitrogen. Thus, while the newly exposed bottom would cause no new problem, the process of dredging would cause release of nutrients from the sediment through the agitation of the bottom material, further degrading water quality in Lake Apopka and the entire chain of lakes.

The agitation caused by the dredging process produces an abnormally high turbidity. A 1970 study at Seattle University showed that this "suspension of the sediments can increase the oxygen uptake rate by a factor of ten" (Dunst et al, 1974). This may cause oxygen depletion and result in fish kills during the period of dredging.

In the process of removing the bottom material, benthic invertebrates will also be removed. These animals serve as food for many game fish. Long-term studies at the University of Wisconsin indicate that more than two years are required for re-establishment of the bottom fauna after dredging (Dunst et al, 1974).

It would currently cost approximately $127 million to dredge all of Lake Apopka (FDPC, 1971; corrected to 1978 cost index from U.S. Department of Commerce, 1978). This estimate does not include disposal cost for the 222 million m^3 of muck that would be removed from the lake. It has been suggested that dredging costs can be offset or even eliminated by processing the muck to produce methane gas which can be sold as fuel. This commercial project would also solve the problem of where to discard the sediments. However, conversations with W.M. Cauthen, of Florida Gas Corporation, indicate several problem areas: (1) Additional technology is needed before this gasification process is commercially feasible. Thus, it would be a minimum of five years before dredging could begin. (2) In order to reduce overhead, a company would only build facilities large enough to process the available muck over a minimum 15-year period. Thus, dredging operations would last at least 15 years, probably longer. (3) In order for the process to be profitable, only the deep holes of muck would be mined, allowing the dredges to remain in the same location for long periods. This would result in very little bottom restoration near shore where it would best improve the lake.

Because of its high costs, dredging is a restoration technique commonly used only on ponds and small lakes. The costs of such a project on Lake Apopka are clearly prohibitive. A commercial, profit-oriented dredging venture would not benefit the lake and would most likely cause further deterioration of the water quality.

Nutrient Diversion

Nutrient diversion is merely the rerouting of nutrient-rich inflows to an area outside of a lake's drainage basin. This restoration technique has been severely criticized because of its effects on recipient waters.

To date $9 million have been spent on nutrient abatement in Lake Apopka. Domestic and industrial inputs have been virtually eliminated; agricultural inputs have been cut by more than 50 percent. Other nutrient sources (rain, springs, runoff, seepage) contribute about 3 times the nitrogen and 9 times the phosphorus contributed by identified man-made sources (DPC, 1972). Further diversion of man-made nutrient sources would do little to improve Lake Apopka's water quality.

Any major diversion of water, with or without nutrients, would alter Lake Apopka's water budget. This would increase the already lengthy water retention period of 4 years, adding to the time that existing nutrients would remain in the lake.

Nutrient diversion has been simulated through a nutrient abatement program in Lake Apopka. Such abatement is necessary to insure the longevity of any subsequent restoration. Nutrient diversion only eliminates further pollution of a lake; it does nothing about nutrients already in the lake, flocculent muck on the bottom or lack of desirable vegetation and fisheries.

Flushing

Flushing a nutrient-rich lake with nutrient-poor water is a means of diluting water quality problems and of decreasing the water retention time of a lake. This technique has been used successfully several times, but documented only for temperate regions (Dunst et al, 1974).

A major consideration in this technique is locating sufficient quantities of nutrient-poor water to perform the flushing. The most reasonable source of water for a Lake Apopka flushing is Little Lake Harris. Little Lake Harris, located only five miles from Lake Apopka, forms an arm of Lake Harris, one of the cleaner lakes in the area (Brezonik and Shannon, 1971). In recent history Lake Apopka and Little Lake Harris were connected by Double Run Swamp. A five-mile canal could be built through this region for $1.2 million (RSB&W personnel, personal communication). Additional expenditures would be required for pumps to move Harris water up a slight gradient to Apopka.

An additional consideration is the effect of the removal of water from the source and its downstream areas. Little Lake Harris, Lake Harris, and Lake Apopka are all components of the Oklawaha Chain of Lakes. The rerouting of water would not change its destination (Lake Eustis), but water from Lake Harris and Little Lake Harris would first flow through Lakes Apopka, Beauclair and Dora (see figure 2.9). Care would have to be taken not to lower the level of Harris to such an extent that poorer quality water from Eustis would begin to flow into Harris via the Dead River. In addition, this process would also flush the poor quality waters of Lakes Beauclair and Dora, while improving the water quality of Lake Apopka.

While the total volume of water in the Oklawaha Chain of Lakes would not change if this procedure were implemented, the flow rates through various channels would change. The flushing rate would have to be limited so as not to tax the channel operating nearest its maximum capacity, the Dora Canal (see Hydrology section).

Like water quantity, water quality of the Oklawaha Chain as a whole would not improve or decline during flushing, but only change with respect to location. As headwaters of the chain, Lakes Apopka, Beauclair and Dora continuously supply nutrient-rich water to the system. Flushing would merely accelerate this process for a short time but would not increase the total amount of nutrients passing through the system. Thus, water quality in downstream areas may decrease temporarily but would return to normal and even improve as Lake Apopka's water quality improves.

As with various other alternatives, flushing is not a complete restoration technique in itself. Flushing alone would not have any effect on the flocculent muck of Lake Apopka and would have little effect, if any, on macrophytes, game fish or benthic invertebrates. In addition, Dr. Brezonik (University of Florida, personal communication) states that given the relatively long retention time of Lake Apopka (about 4 years), even doubling the flow through the lake (if that much water were available) would not have much effect.

Aeration

Aeration of a lake is the use of compressed air, pure oxygen, or mechanical pumping to increase the dissolved oxygen content of the lake, especially of the bottom water (Fast, 1975). Many eutrophic lakes experience semi-annual periods of oxygen depletion, with microbial decomposition of organic matter primarily responsible for this shortage of oxygen (discussed in the Flora section). Aeration has long been used in temperate lakes and reservoirs to alleviate dissolved oxygen depletion (Smith, Knauer, and Wirth, 1975).

Lake Apopka is shallow and thus well-mixed by wind. Oxygen-rich surface water constantly replaces oxygen-depleted water near the bottom. In spite of tremendous amounts of decomposing organic matter, no significant oxygen depletion has been documented in the lake (however, it is quite possible that dissolved oxygen levels are very low at the muck/water interface). From this standpoint, aeration of the lake would not improve water quality or lead to the recovery of any desirable species of plants or animals.

Bottom sediments may also be affected by aeration. Experimental work tentatively suggests that release of compressed air at the water-sediment boundary of a lake may enhance the aerobic* decomposition of organic bottom sediments (Martin, University of South Florida, personal communication). Unfortunately, this process is poorly understood, with key questions still to be investigated. Decomposition of organic matter should result in the conversion of nutrients into forms that promote phytoplankton production. This could compound water quality problems in a lake such as Apopka. Also unknown is the time required for aeration to decompose a given amount of organic sediment. Until these questions are investigated, the use of aeration to deal with unconsolidated sediments will remain a speculative possibility.

Robert Heideman (personal communication), an aeration consultant, feels that the most significant deterrent to aeration as a successful restoration technique for Lake Apopka is the size of the lake. He believes that with current technology only half of the lake could be aerated at one time. His estimated cost for a 50 percent aeration effort is $3.4 million for the first year and $0.7 million for each of an indeterminant number of subsequent years. Equipment could then be moved and the remaining portion of the lake could be aerated, again for an indeterminant number of years.

Even if half of Lake Apopka were successfully aerated, the remaining half would still be covered with unconsolidated sediments. After relocation of the aeration system in the unaerated half of the lake, some of the unconsolidated sediments would shift to the previously treated half. This would tend to negate any recovery of macrophytes and benthic macroinvertebrates.

Thus, the size of Lake Apopka and the nature of its bottom sediments eliminate aeration as a plausible restoration technique. Heideman (personal communication) summarized the problems associated with aeration by stating, "At this time, aeration is not a suitable method of restoration for Lake Apopka."

Drawdown and Sediment Consolidation

Substantial drainage of a lake, with subsequent exposure of the bottom to drying effects of the atmosphere and sunlight, constitutes a process known as drawdown. This lake restoration technique simulates extreme drought in a lake with a naturally fluctuating water level.

The water content of organic sediment in eutrophic lakes often exceeds 90 percent of the sediment volume (Dunst et al, 1974). Exposure of this flocculent sediment and subsequent drying causes it to collapse under its own weight while undergoing a permanent rearrangement of its physical structure, a process called consolidation.

As a result of consolidation the lake is deepened; thus, this process serves as an alternative to dredging as a means of lake deepening. Unlike dredging, drawdown with consolidation does not remove organic sediment. However, the lake deepening does decrease the ratio of sediment surface area to water volume, thus diluting the nutrients entering the water from the sediment. In addition, consolidation changes the sediment in such a way that its effect on some parameters of water quality is reduced. Fox et al (1977), in experiments with Lake Apopka sediments, found that sediment consolidation provided for lower turbidities, higher dissolved oxygen values, lower temperatures and reduced phytoplankton after lake refill.

In rearranging the structure of sediment, consolidation stabilizes the fluid-like muck. This compacted bottom, upon refill, provides a firm base for rooted aquatic macrophytes, a suitable material for game fish breeding grounds, and a bottom that will provide for an increased diversity of benthic invertebrates (Fox et al, 1977).

The drawdown period itself also provides some benefits, as it simulates extreme natural lake level fluctuation. Some aquatic and semi-aquatic plants require that their seeds be dried before they will germinate; drawdown will provide an opportunity for this drying. In addition, some rooted aquatic plants will be able to start growing further from the shore in the temporary shallow areas. Upon refill, these plants may grow fast enough to keep a portion of their photosynthetic structures close to the surface of the rising water. In such a case, the littoral zone will be effectively increased.

FG&FWFC personnel have identified ten natural, artificial and accidental drawdowns in the state of Florida. Of these ten, the artificial drawdown of Lake Tohopekaliga is most pertinent to Lake Apopka's proposed restoration. Lake Tohopekaliga is 70 percent as large as Lake Apopka but slightly deeper. Like Lake Apopka it had large areas of unconsolidated sediment; however, Lake Tohopekaliga had 39 percent of its area designated vegetated littoral zone as opposed to Lake Apopka's 0.03 percent. After the lake's 1970-73 drawdown and refill, FG&FWFC personnel noted vertical sediment consolidation of up to 80 percent, a 16 percent increase in the vegetated littoral zone, a three- to fourfold increase in fish food organisms and a 370 percent increase in the value of the lake's fishery.

As with most drawdowns in Florida, conditions in Lake Tohopekaliga have deteriorated since the initial improvements. Lake Tohopekaliga, as well as each of the other nine drawdown lakes in Florida, did not undergo a nutrient abatement program before its restoration. Thus the nutrient input that had accelerated the lakes' eutrophication in the first place had not been eliminated, and, in fact, had probably increased due to population growth. Lake Apopka, on the other hand, is undergoing a nutrient abatement program at a cost of $9 million which is scheduled for completion in 1980.

The drawdown process, leading to sediment consolidation, is not free of detrimental effects. One major problem is the effect of such a drawdown on the meteorology of the surrounding area. A large body of water, such as Lake Apopka, changes temperature very slowly. During a sudden cold spell the lake remains warmer than the air temperature. Prevailing northerly winds, blowing across the lake, are heated by the warmer water before they reach the citrus groves on the southern shore. Thus, the lake offers some frost-freeze protection to these citrus groves. Removal of the water during the frost-freeze season could result in increased damage to the citrus crop and citrus groves.

Lake Apopka's water is currently used for irrigation by the citrus groves west and south of the lake and by the muck farms to the north. A drawdown may necessitate the drilling of wells or some other procedure to supply uninterrupted irrigation.

Questions have been raised as to the effect of low quality Lake Apopka drawdown water on downstream water quality. As the headwaters of the chain, Lake Apopka water already flows to downstream lakes. Hahn (1978) points out that "water directly downstream from Apopka (Lakes Dora and Beauclair) is of poorer quality than Apopka."

In 1971 an experimental drawdown was performed on Lake Apopka, but cut short due to public concern when some fish and alligators died. No evidence was found associating the drawdown with the animal kills (Fla. Dept. of Health and Rehabilitative Services, 1971). However, some personnel of FG&FWFC (Johnson, personal communication) believe that a few alligators died of exposure when they became bogged down in the muck and could neither reach land nor water. In a major drawdown, the concentration of fish in small pools is expected to cause fish kills. Reduction of massive rough fish populations is a well-recognized method in the restoration of sportfishing. Adverse side effects of the expected fish kills could be avoided through the commercial harvesting of fish during the drawdown. Alligators, being air breathers and motile, are not expected to be killed during the drawdown. However, a drawdown during their reproductive season could eliminate that year's brood (Haines, FG&FWFC, personal communication).

Past drawdowns have experienced vast growths of terrestrial vegetation on the exposed portion of the lake bottom. These plants aid in drying the sediment by giving off water to the atmosphere; however, they may also shade the sediment from the drying effect of the sun. The roots of these plants form an interwoven mesh that holds the sediment together and prevents erosion. However, when the lake is refilled much of this vegetation becomes only partially submerged, creating an aesthetically unappealing view. In addition, decomposition of this vegetation releases nutrients into the water, and creates an additional oxygen demand. These problems could be avoided by harvesting the vegetation before or during refill.

In 1972 DPC estimated drawdown costs at $2.5 million (corrected to 1978 cost index, Department of Commerce, 1978). After incorporating various engineering techniques to avoid drawdown problems specific to Lake Apopka, the engineering firm of Ross, Saarinen, Bolton & Wilder (RSB&W), in October, 1978, estimated the cost of drawdown at $14 million.

Drawdown and sediment consolidation would be expected to improve water quality and sediment conditions while providing a start for the desired sportfishery. While the cost of drawdown is fairly high, it is less expensive than another equally effective technique, dredging, and the cost estimate provides for solutions to many problems usually associated with drawdowns.

SECTION 4

DESCRIPTION OF SELECTED ALTERNATIVE

Selection

An examination of Table 4.1 indicates that only two of the restoration techniques considered will result in the improved water quality and bottom conditions needed for significant physical and biological restoration of Lake Apopka. Of the two methods, dredging is prohibitively expensive; therefore, drawdown is selected as the logical alternative.

Other alternatives can be employed in conjunction with the selected alternative as secondary techniques. These secondary techniques, as discussed below, will maximize the benefits and minimize the adverse effects of drawdown.

Nutrient diversion (or nutrient abatement) is a prerequisite for restoration. Without reducing the causes of the lake's deterioration, any restoration will be short-lived. A $9 million nutrient abatement program on Lake Apopka has been implemented and should be finished before the restoration project is completed.

To avoid future deterioration of Lake Apopka bottom conditions due to unavoidable nutrient inputs, the lake should be put on a schedule of fluctuating water levels. Such fluctuation has been shown to simulate natural conditions in most lakes and provide beneficial maintenance of the littoral zone (Fox, Brezonik, and Keirn, 1977).

Constraints

The Department of Environmental Regulation has required that the engineering design of the Lake Apopka drawdown provide for the protection of people and property around the lake and in downstream areas. The design must also provide for the protection of downstream water quality. To meet these restrictions, the following eleven constraints have been placed upon any proposed drawdown design:

Table 4.1. Comparison of Restoration Techniques.

Method	Benefits	Disadvantages	Downstream Effects	Ecological and Economic Hazards	Recommendation
No Action.	No expense.	Little or no improvement of water quality or bottom.	None.	Possible continuing deterioration of lake and its economy.	Reject.
Fluctuation.	Little added expense; some possible benefits to littoral zone.	No improvement to majority of bottom; little change in water quality.	None.	Possible loss of dock use during low water; possible flooding damages during high water.	Secondary.
Chemical Sedimentation.	Relatively inexpensive; effectively improves water quality.	Further deterioration of bottom; water quality improvement only temporary.	Beneficial effects of flushing via clean water from Apopka.	Increased muck problem.	Reject (Possible Secondary).
Dredging.	Permanent improvement of bottom; eventual improvement of water quality.	Prohibitively expensive; takes too long; difficulty in disposing of dredged materials.	Increased turbidity from Apopka outflow.	Increased turbidity. Possible habitat loss with soil placement.	Reject.
Nutrient Diversion. (Abatement)	No further deterioration.	No significant improvement of water quality or bottom.	Decreased rate of deterioration due to Apopka outflow.	None.	Prerequisite for restoration (near completion).
Flushing.	Improved water quality.	No improvement of bottom.	Temporary change in flow patterns; temporary decrease in water quality.	Temporary water level changes on some lakes may cause temporary loss of dock use or possible flooding damages.	Reject (Possible Secondary)
Aeration.	Possible improvement of bottom.	Possible deterioration of water quality; takes too long.	Possible deterioration of water quality due to Apopka outflow.	Possible increase in phytoplankton and turbidity.	Reject.
Drawdown.	Improvement of bottom; eventual improvement of water quality.	Loss of lake use for one year.	High water for several months followed by low water for several months; possible benefits from fluctuation.	Frost-freeze danger; possible flooding damages.	Recommended Alternative.

1. Lake level must be maintained at 19.5 m (64 ft) msl during December, January, and February for citrus protection against frost/freeze.

2. Lake level must be maintained at 17.7 m (58 ft) msl for two months, preferably May and June, for muck consolidation and drying.

3. Dora Canal open drainage flow must not exceed 757 m^3/min (200,000 gpm) at any time during drawdown and refill.

4. Sediment transport and deposition in downstream lakes and canals must be prevented to the maximum feasible extent.

5. Water quality must not be degraded below standards set in Chapter 17-3, Florida Administrative Code, or below existing conditions. It is recognized that some water quality parameters in these waters already exceed allowable limits.

6. Backflow from Lake Eustis to Lake Harris must be prevented at all times.

7. Irrigation waters must be provided during drawdown for the muck farms to the north and east of Lake Apopka.

8. Irrigation needs must be determined and provided to citrus groves during drawdown.

9. Aquatic fauna kills in Apopka and downstream lakes are to be prevented or minimized. Contingency plans must be prepared covering unavoidable occurrences.

10. While sufficient water for emergency refill of Lake Apopka may be stored in downstream lakes, the water levels must not conflict with the allowable Water Management District water level ranges.

11. Coordination with DER Dredge and Fill Permitting must be provided on all plans.

Description

The current design for the drawdown, as presented by RSB&W, consists of eight phases. Each of the phases is described below within its tentative time schedule. Because of the seasonality of constraint #1 (frost/freeze protection) any major delays in the schedule must be made in one-year units. A more detailed description of the project is presented in Appendix B in the form of the actual engineering design. Figure 4.1

indicates the locations of the various construction sites. Numbers in parentheses following the initial mention of each site correspond to numbered locations in Figure 4.1.

Phase I. EIS Evaluation, Design, Bidding/Award (12-19-77 to 4-30-79).

The production of this EIS and the engineering designs presented herein have been carried out as a part of Phase I, as will be the evaluation of this EIS and project proposal. Bidding and awarding of construction and maintenance contracts will be implemented during the later stages of this phase.

Phase IIa. Initial Construction (7-1-79 to 1-31-80).

A. Dead River. To prevent backflow of lower quality water from Lake Eustis into Lake Harris (constraint #6), a dam and flow control structure (1) will be built in the Dead River. A boat lift will be included so as not to hinder boat traffic between Lake Harris and the remainder of the Oklawaha Chain of Lakes. A site will be required for this facility adjacent to U.S. Route 441. The proposed site includes an existing road and an abandoned building on the north side of the highway and east bank of the river. The abandoned building will be used as a control building for the operator of the flow control structure and boat lift.

1. Coffer dam and flow control device. The coffer dam will span approximately 162 m (530 ft) and will be constructed 4.6 m (15 ft) wide to an elevation of 20.0 m (65.6 ft) msl. In order to prevent Lake Harris from exceeding its maximum operating level of 19.4 m (63.5 ft) msl, a 46 m- (150 ft-) wide weir with removable stop logs will be constructed in the coffer dam. During the drawdown and holddown phases, the weir will be set at an elevation of 20.0 m (65.5 ft) msl to prevent water from backing up the Dead River and entering Lake Harris. The stop logs can be removed in the weir as required during this period to prevent Lake Harris water from exceeding 19.4 m (63.5 ft) msl. During the refill period, the adjustable weir will be used to control the rate of flow from Lake Harris to Lake Eustis.

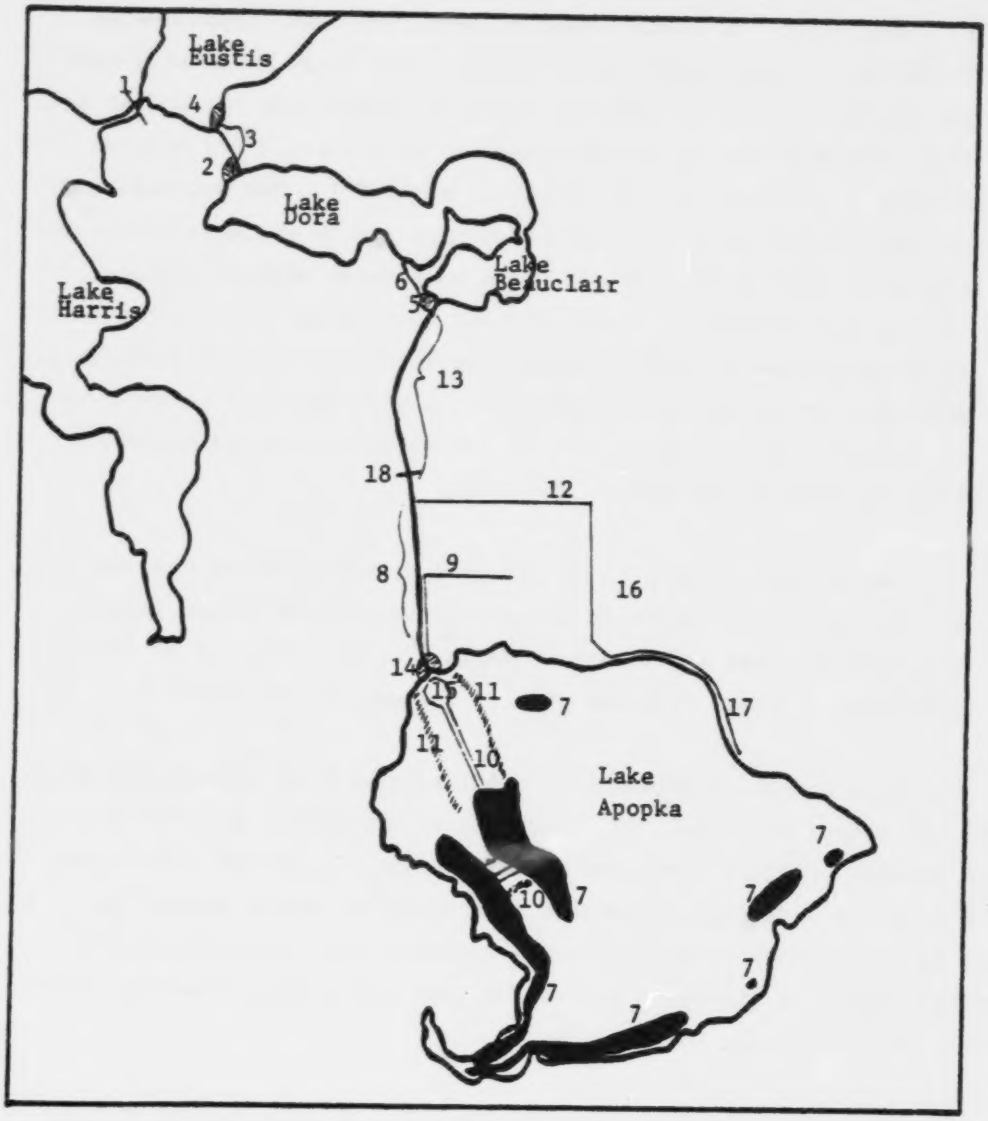
Lake Eustis
1
4
3
2
Lake Dora
Lake Beauclair
6
5
Lake Harris
13
18
12
9
8
16
14
15
11
7
17
11
10
Lake Apopka
7
10
7
7
7
7
7

Figure 4.1. Construction site for Lake Apopka Drawdown Project.

1. Dam, flow control structure and boat lift on Dead River
2. Dora Canal By-pass pump station
3. Dora Canal transmission main by-pass
4. Dora Canal drawdown dissipator and refill pump station
5. Lake Beauclair refill pump station
6. Lake Beauclair refill pump station access road
7. Deep holes
8. Structural reinforcement of dikes
9. Upgraded muck farm road
10. Deep hole channel
11. Spoil ridges from dredging of deep hole channel
12. East-West McDonald Canal
13. Dredging to remove silt
14. Lake Apopka drawdown pump station
15. In-lake sedimentation basin
16. North-South McDonald Canal
17. Outside perimeter canal
18. Apopka-Beauclair Lock and Dam pump station

2. Boat lift. A 10-ton capacity self-propelled, four-wheeled Travel Lift crane supported on finger piers built integrally with the coffer dam will be used to transport boats over the coffer dam. This equipment has an inside dimension of 4.5 m (14 ft) and can provide a vertical lift of up to 4.6 m (15 ft). Two automatically controlled and energized flexible slings can be adjusted to accommodate each boat at the bow and stern to provide support during lifting and transport. Boats without the typical hull configuration (such as houseboats with pontoons) will require special supporting methods. It is estimated that about 10 minutes would be required to transport an average 6.1 m (20 ft) inboard-outboard motorboat from one side of the dam to the other.

Ample dock space will be provided on each side of the dam so that boats waiting to be lifted can be tied up in the interim. A system of docks and temporary walks will be installed to convey occupants of boats from one side of the dam to the other.

B. Dora Canal. Constraint #3 requires that flow through the Dora Canal not exceed 757 m^3/min (200,000 gpm) at any time. Because of the large amounts of water that must be moved within a limited time frame, RSB&W proposes that during drawdown some water be pumped around the canal in a large pipe. This proposal requires the construction of a pumping station at the south end of the pipe and a large-diameter transmission main from Lake Dora to Lake Eustis.

1. Dora Canal By-Pass Pump Station (2). A small parcel of land will be required at the Lake Dora entrance to the Dora Canal in order to construct pump facilities to pass a portion of the canal flow through the pipeline. The site will be located on the southwest bank at the entrance to the canal on presently vacant land. An existing street serving residents in the area will require extension to the site, and sufficient parking area will be required for equipment and the operator's trailer.

2. Inlet sump. Pumping equipment will require a minimum of 2.7 m (9 ft) of water above the pump inlet. Therefore, a sump will be excavated to a bottom elevation of 15.8 m (52 ft) msl, a width of 4.9 m (16 ft) and a length of 17.1 m (56 ft). Sheeting will be driven around the sump to create a box. The top of the sheeting will be cut off at 18.9 m (62 ft) msl to form a weir which will allow only the clearer surface water to spill into the sump during the drawdown and holddown phases. Large pieces of broken concrete will be placed in the bottom of the sump and outside the sump, adjacent to the sheeting, to prevent erosion. A vegetation net and wildlife net will be installed immediately upstream of the sump to prevent floating vegetation, fish, alligators, etc. from entering the sump.

3. Dora Canal Transmission Main By-Pass through Tavares (3). As indicated in Figure 4.2, a pipe approximately 2286 m (7500 ft) long, will be required through Tavares.

The transmission main will proceed from the drawdown pump station across the Dora Canal in a trench on the canal bottom, thus keeping the canal open to boating. Under the railroad bridge the pipe will be placed on the bank of the canal. A trench will be excavated within the bank in which the pipe will be placed. The pipe will be partially laid in a trench from the railroad bridge to Irma Street. At this point the pipe will be placed totally within a trench under the street. From this point to Duncan Drive, the pipe will be placed partially within a trench constructed adjacent to the railroad tracks.

The pipe will be either jacked under Duncan Drive or installed by open excavation. From this point to the U.S. Route 441 bridge the pipe will be placed partially within a trench excavated along the railroad tracks. The pipe will be placed either in the canal under U.S. Route 441 and the railroad bridges or on the side of the bank. The transmission main will terminate just off shore on the Lake Eustis end of the Dora Canal.

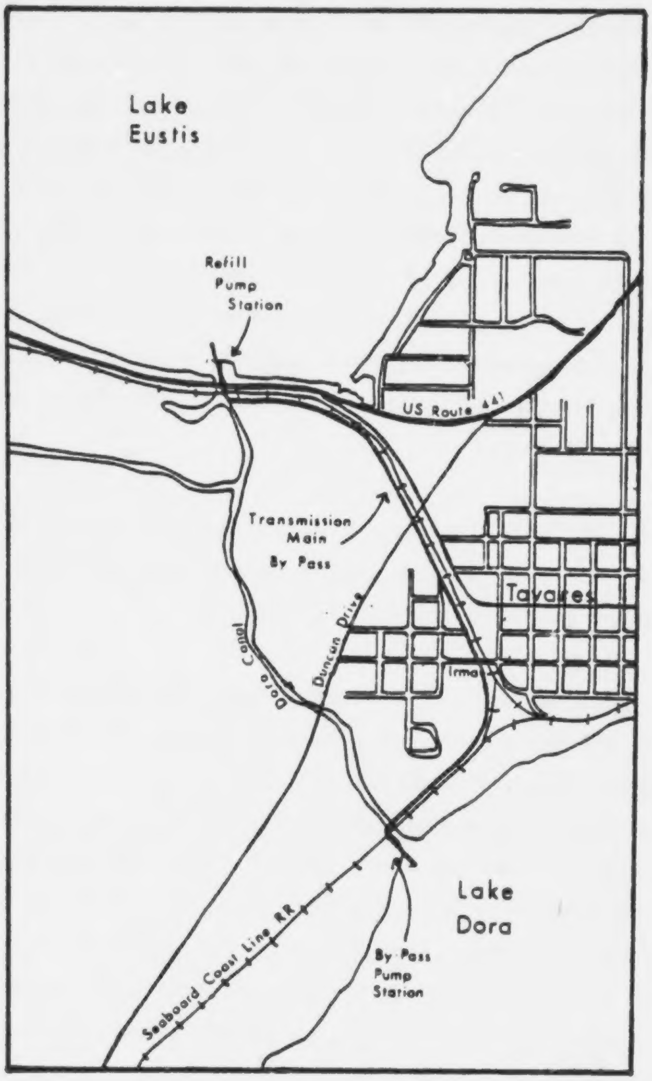
Lake Eustis
Refill Pump Station
US Route 441
Transmission Main By Pass
Duncan Drive
Dora Canal
Tavares
Irma
Lake Dora
By Pass Pump Station
Seaboard Coast Line RR

Figure 4.2. Path of Dora Canal transmission main bypass.

Most of the easement required to construct the pipelines belongs to the Seaboard Coast Line Railroad Company. However, public streets within Tavares will require crossing and some utility relocation may be necessary. At the termination of the project, the property will be restored to its original condition. The pipe installed under Duncan Drive and Irma Street may remain at the discretion of town officials.

4. Energy dissipation structure. An energy dissipation structure will be required at the termination of the pipeline. This will entail the construction of a steel-sheeted sump filled with riprap to prevent scouring in Lake Eustis. An access road presently exists from U.S. Route 441 to the site. A turn around area will be provided off the access road.

There presently is not sufficient land at the site to hold all of the facilities required. Additional land will be provided by sheeting a short distance into the lake and filling in behind the sheeting. After completion of the project, the area will be restored to a condition which is satisfactory to permitting agencies.

5. Protection in the Dora Canal. Within the Dora Canal, existing supports for highway and railroad bridges may require protection. Sheeting or riprap could be placed around the footings to protect them against scouring.

C. Apopka-Beauclair Canal. All of the water pumped out of Lake Apopka during drawdown must pass through the Apopka-Beauclair Canal. To facilitate the flow of this massive volume of water within the required time interval while meeting the requirements of constraints #4 and #11 (sediment transport and water quality), a great deal of preparative construction will take place along the canal.

1. Lake Apopka Drawdown Pump Station (14). This site will require the use of a small parcel of land at the Apopka-Beauclair Canal outlet from Lake Apopka. The major portion of required land is on

the east bank of the canal. Fuel oil storage, trailers and vehicle parking will be located here. Major construction at this site will include the excavation of a sump for the pumps and the construction of a coffer dam to support the pumps.

An existing muck farm road (9) will require up-grading from the service road at the water tank-railroad siding area to the Lake Apopka drawdown pump station. The existing road will require widening in certain areas and general improvement to serve the heavy construction vehicles that will be using the road. The muck farm road from the terminus of U.S. Route 448 to the water tank appears to be adequate.

2. Structural Reinforcement (8). Dike protection will be required at spots along the Apopka-Beauclair Canal. Dike elevations will be brought up to 21.3 m (70 ft) msl at Lake Apopka and 21.0 m (69 ft) msl upstream of the lock and dam. Below the lock and dam only scattered areas will require fill to raise the dike to 20.1 m (66 ft) msl. Fill material used to raise dike elevations will be coarse sand available locally. Riprap will be required just north of the Lake Apopka Lock and Dam to protect the sides of the dikes from scouring. The existing footings of railroad and highway bridges along the Apopka-Beauclair Canal may require protection. This could be accomplished by steel sheeting, riprap or other suitable means.

3. Dredging (13). Silt in the bottom of the Apopka-Beauclair Canal north of U.S. Route 448 will be removed via a floating hydraulic dredge prior to drawdown. This is necessary to prevent washing of silt into the downstream lakes. Spoils will be discharged onto the side slopes of the dike away from the canal. Where private property abuts the dike, spoils will be trucked for disposal elsewhere.

4. Construction of a 24-hectare (60-acre) on-land sedimentation basin was proposed to settle silt and spent chemicals from treated Lake Apopka water. The cost of this basin, estimated by RSB&W, was

prohibitively expensive. An alternative in-lake sedimentation basin has been proposed.

5. Coffer dam. Approximately 183 m (600 ft) north of the mouth of the Apopka-Beauclair Canal, a coffer dam will be built across the breadth of the canal and tied into the existing berm along both banks. The coffer dam will be about 4.6 m (15 ft) high, with the top of the dam at an elevation of 22.9 m (75 ft) msl. The dam will be 49 m (160 ft) wide to provide sufficient space for pumps, discharge manifolds and vehicle access. An estimated 6900 m^3 (9000 yd^3) of fill material will be required to construct the dam.

6. Sump. In order for the pumps to function properly, a minimum water depth of 3.7 m (12 ft) must be maintained over the pump inlet. Therefore, a sump will be excavated to a bottom elevation of 13.6 m (44.5 ft) msl, a width of 6.1 m (70 ft), and a length of 30.5 m (100 ft). The bottom of the sump will be lined with riprap to prevent scouring of bottom sediments.

7. Weir. An adjustable intake weir will be located just upstream of the pump sump. This will permit only the clearer surface waters to flow into the sump and be pumped downstream. This weir will use 4.6 m (15 ft) long, wooden stop logs held in place between the flanges of vertical wide flange steel I-beams. These stop logs will be removed when necessary as the water level drops. A catwalk above the weir will provide access for workmen.

Attached to the intake weir, a 139 m^2 (1500 ft^2) wildlife net will be used to keep alligators, turtles, etc. from entering the sump and intake pipes. A 37 m^2 (400 ft^2) vegetation net will be located just upstream of the intake weir to keep floating plants away from the pumps. The wildlife net will extend to the bottom of the canal whereas the vegetation net will only reach 0.6 m (2 ft) below the water surface.

D. Lake Apopka. An in-lake sedimentation basin (15) will be dredged at the mouth of the Apopka-Beauclair Canal. The basin will be excavated to a bottom elevation of 14.6 m (48 ft) msl. A 46 m (150 ft) wide approach channel will run from the coffer dam, pumps and adjustable weir 177 m (580 ft) south, to the mouth of the Apopka-Beauclair Canal at a bottom elevation of 15.2 m (50 ft). The approach channel will join the sedimentation basin and widen from its 46 m (150 ft) width to 610 m (2000 ft) over a distance of 274 m (900 ft). The basin width will remain at 610 m (2000 ft) for the next 457 m (1500 ft) and then decrease to 107 m (350 ft) over the next 488 m (1600 ft) distance. The basin, as designed, has a length of 1219 m (4000 ft), is 610 m (2000 ft) at its widest point, covers an area of 48 hectares (120 acres), and has a detention time of 20 hours.

Continuing south from the basin a 1.5 m (5 ft) deep, 107 m (350 ft) wide, 6.4 km (4 mi) long channel (10) connects the sedimentation system with two deep holes on the western side of the lake. During the later stages of drawdown and holddown, when the water level is near its lowest point, this channel will serve to drain the deeper holes of Lake Apopka and will also aid in sedimentation while the silt-laden water slowly flows to the basin.

Excavation of the sedimentation basin, approach channel and deep hole channel will be accomplished using a floating hydraulic dredge. Clay and muck spoils will be pumped back into the lake in two low ridges (11) parallel to the basin and 305 to 610 m (1000 to 2000 ft) to either side. These ridges will be far enough away so as not to cause the excavations to collapse, and will serve as barriers to prevent the flow of flocculent muck from filling the channels and basin. Sand encountered during the dredging of the last 1.4 m (4.5 ft) of the sedimentation basin depth will be discharged relatively near the basin. This will result in a firmer crust after consolidation and provide a more suitable habitat for game fish breeding.

During drawdown and holddown a floating hydraulic dredge will remove settled solids from the channels and basin. Spoils will be disposed of as they were during the original excavation of the structures.

E. Muck Farm Irrigation.

1. Zellwood Drainage District. The 4636 hectares (11,455 acres) of muck farms east of the Apopka-Beauclair Canal will be irrigated utilizing water from the Apopka-Beauclair Canal via the East-West McDonald Canal (12), the North-South McDonald Canal (16), and the outside perimeter canal (17) (lying outside of the farmers' dike, but inside the area known as the Willows Dike). The plan calls for cleaning and enlarging some of the existing canals and repairing breaks and low spots in the Willows Dike to an elevation of not more than 19.8 m (65 ft) msl. A water control structure, consisting of a parallel set of corrugated adjustable flashboard risers, will be located at the south end of the North-South McDonald Canal. In addition to providing irrigation water, the reconstructed perimeter canal will protect the farmers' dike from the destructive effects of drying during holddown.

2. Clay Island Farms. Clay Island Farms are currently irrigated from the existing perimeter canal (west of the Apopka-Beauclair Canal) which is, in turn, connected with the Apopka-Beauclair Canal. By extending this connection past the proposed coffer dam, ample irrigation water will be supplied during the entire project. In order to regulate water level in this canal, a water control structure (similar to the one proposed above) is required.

3. XXX Products (Pine Island). XXX is predominantly a soil mining operation with muck farming being a maintenance operation on soils which are to be mined in the future. Pumps are run 24 hours, 7 days per week, to maintain water levels low enough so the soils can be mined. As a result, no shortage of water is foreseen for this site.

If a water shortage should occur at this site, alternative supplies are available. Several capped artesian wells, presently existing on site, could be uncapped and pumped to provide water. If necessary, a short canal could be dug from an existing pump site to a deep hole (7) offshore from Montverde.

4. Duda Farms and Frank Farms. The irrigation systems of these farms are connected directly to the Apopka-Beauclair Canal or the McDonald Canal and will receive water throughout the restoration project, thus no alternative plans are necessary.

F. Citrus Grove Irrigation.

1. Groves irrigated from a deep well tapping the Floridan Aquifer. The decline in the production capability of these wells, due to the drawdown, will be so slight as to not adversely impact irrigation.

2. Groves irrigated from Lake Apopka. To provide water to the existing irrigation pumps, a well, tapping the Floridan Aquifer will be constructed. The well will be furnished with a deep well turbine pump and right angle gear drive. A portable trailer-mounted gasoline engine will provide power to the pump. The deep well pump will discharge directly into existing irrigation systems.

3. Groves not currently irrigated. An analysis (by RSB&W) indicated that the most reliable and cost effective irrigational system for these groves is a mobile velocity gun on a high-rise traveler. The gun will be supplied from a deep well and located by truck or tractor. This system will be capable of providing sufficient water to existing unirrigated groves to overcome any impacts of the drawdown.

Phase IIb. Gravity Drawdown (9-1-79 to 2-1-80).

By opening the water control structure on the Apopka-Beauclair Canal, the water level of Lake Apopka will be lowered by gravity from its average of 20.3 m (66.5 ft) msl to 19.5 m (64 ft) msl during this five-month period. It has been determined that a water level of 19.5 m (64 ft) msl will provide sufficient frost/freeze protection to the citrus groves on the south shore of Lake Apopka during this period (Bartholic and Bill, 1977).

Phase III. Pumped Drawdown (3-1-80 to 5-31-80).

On 2-1-80 the water control structure on the Apopka-Beauclair Canal will be closed to allow completion of construction and dredging in Lake Apopka. On 3-1-80, pumping will begin at a water level of 19.5 m (64 ft) msl. During the following three months pumping will reduce the water level to 17.7 m (58 ft) msl. After drawdown (and during holddown) downstream water levels will reach but not exceed, the following elevations:

Beauclair	19.5 m (64 ft) msl
Dora	19.5 m (64 ft) msl
Eustis	19.4 m (63.5 ft) msl

The coffer dam in the Dead River will prevent backflow of Lake Eustis water into Lake Harris and, at the same time, will allow clean water to be stored in Lake Harris for use during the refill cycle. As a result of the dam, the water level in Lake Harris will reach a maximum of 19.4 m (63.5) msl. With the exception of Lake Apopka, all changes in water levels will be within the range of SWFWMD's legal desirable levels for each lake.

To achieve these water levels within the time constraint, water will be pumped through the A-B Canal at a rate of 1232 m^3/min (780 cfs) and through the Dora Canal By-Pass at a rate of 552 m^3/min (325 cfs). Flow through the various channels will not exceed the maximum capacity for each channel.

Phase IV. Holddown (6-1-80 to 7-31-80).

Rainfall plus discharge from Apopka Springs, muck farms, and various miscellaneous sources, minus losses due to evaporation, will produce a net inflow to Lake Apopka amounting to 855 m^3/min (503 cfs) during design conditions (heavy rainfall). As a result, pumping will be required to maintain the lake's water level at 17.7 m (58 ft) msl during holddown. Additional muck farm effluent into the Apopka-Beauclair Canal will increase the total flow through the canal during holddown to 962 m^3/min (566 cfs). Pumping through the Dora Canal By-Pass during holddown will continue at the same rate of 552 m^3/min (325 cfs).

During inclement weather, it may be necessary to cease pumping because of mixing and turbidity in the sedimentation basin. If this is necessary, pumping will be suspended until the sedimentation basin begins to clear. When pumping begins again, a sufficient number of pumps will be operated long enough to bring the water level back down to 58.0 ft msl, as quickly as possible.

Phase V. Refill (8-1-80 to 11-30-80).

Pumps used during drawdown and holddown will be moved to near locations and will be used for refill.

A. Lake Beauclair Refill Pump Station (5). A small parcel of land at the Lake Beauclair end of the Apopka-Beauclair Canal will be required for construction of a coffer dam, a sump for the pumps to draw from, parking area and fuel storage area. A 91 m- (300 ft-) long channel will be dredged from the sump out into Lake Beauclair. Upon termination of the project the land will be restored to its original condition.

1. Coffer dam. A coffer dam will be built across the breadth of the canal (about 37 m or 120 ft) and tie into the existing ground along both banks. The coffer dam will be built to an elevation of 19.8 m (65 ft) msl with a width of 12.2 m (40 ft) to provide space for pump equipment and vehicle access.

2. Lake Beauclair Refill Pump Station Access Road (6). The existing farm road which runs from Shirley Shores Road to the citrus groves east of the proposed pump station site will require upgrading and extending to the pump station site. Upon project completion, the area could be restored to its original condition or the access road could remain at the land owners' discretion.

3. Sump. A sump will be excavated to a bottom elevation of 12.5 m (41 ft) msl, a width of 5.2 m (17 ft) and a length of 16.8 m (55 ft). The bottom of the sump will be lined with large riprap to prevent scouring. Sheeting driven around the sump will be cut off at 15.8 m (52 ft) to allow only the clearer surface water to enter the sump. Vegetation and wildlife nets will surround the sump to keep floating plants, alligators, turtles, etc., away from the pumps.

B. Apopka-Beauclair Lock and Dam refill station (18). The last of three refill pumping facilities will be located in the Apopka-Beauclair Canal just downstream of the lock and dam.

1. Coffer dam. A 30 m (100 ft) wide coffer dam will be built across the canal and will tie into the existing ground along both banks. The dam, with a top elevation of 21.3 m (70 ft) msl and a width of 12.2 m (40 ft), will require 918 m^3 (1200 yd^3) of fill during construction.

2. Access. A dirt road leading from Astatula Road to the east bank of the canal will be used for access to the site. The road will probably require some modifications as the grade may be too steep for heavier vehicles. Changes will probably consist of reducing the grade to Astatula Road and providing parking and a turn around at the site.

3. Sump. In order to maintain the required minimum of 3.7 m (12 ft) of water over the pump inlet pipes, a sump will be excavated with a bottom elevation of 14.6 m (48 ft) msl. The riprap-lined sump will be 5.3 m (17 ft) wide and 13.4 m (44 ft) long. Sheeting driven around the sump will be cut off at an elevation of 17.7 m (58 ft) msl to allow only the clearer surface water to reach the suction pipes.

C. Dora Canal Refill Pump Station (4). The energy dissipator and the access road constructed for the drawdown will be utilized for the refill pump facilities. A parcel of land on the east bank of the canal near Lake Eustis will be needed for the pump, discharge piping, fuel storage, parking and trailer. The energy dissipator, used during drawdown, will be utilized as a sump for the refill pumps. The 2.1 m (85 in.) pipe will be removed from the sump and seven pumps will be installed with their intake pipes placed in the sump. No additional work will be required to convert the energy dissipator to a sump as it will be constructed initially for these dual purposes. The features of the structure will be identical to the sump described earlier for the drawdown-holddown phases. Water will be pumped through the bypass transmission main in reverse from the drawdown cycle. At the termination of the project the site would be restored to its original condition.

Phase VI. Cleanup (12-1-80 to 3-31-81).

Remove all facilities and restore to pre-construction conditions at property owners' option.

Phase VII. Lake Beauclair Restoration (12-1-80 to 6-1-81).

After the restoration of Lake Apopka is complete, Lake Beauclair will be restored, thereby mitigating any adverse impacts which might have occurred in Lake Beauclair as a result of the Lake Apopka project.

A. Predrawdown Phase. During the winter following the completion of the Lake Apopka restoration, additional facilities needed for the Lake Beauclair restoration will be constructed. Coffer dams between Lake Beauclair and Lakes Dora and Carlton will be constructed. Necessary irrigation modifications will be made. These modifications include the location of temporary water supply pumps near Lakes Dora and Carlton, and the drilling of wells for use by the mobile irrigation facilities. Mobile irrigation facilities will be relocated from the citrus groves south of Lake Apopka; groves near Lake Beauclair will be surveyed to assure access by the mobile irrigation facilities. A deep hole channel will be necessary to drain the deeper portions of Lake Beauclair. The channel will be approximately 914 m (3000 ft) long, 64 m (210 ft) wide with 15:1 side slopes and will average 1.3 m (5 ft) in depth.

B. Drawdown Phase. On March 1 of the year following the Lake Apopka restoration, the drawdown of Lake Beauclair will begin. Drawdown of Lake Beauclair to 16.2 m (53.0 ft) msl will require the use of three of the five existing pumps located at the pumping stations on Lake Beauclair and the Apopka-Beauclair Canal Lock and Dam. Drawdown will be accomplished in 14 days by pumping water from Lake Beauclair into Lake Apopka at a rate of 9550 liters/sec (151,400 gpm).

If inclement weather mixes Lakes Beauclair, pumping will be suspended until the lake settles and drawdown can proceed without posing a threat to Lake Apopka's water quality. If, at any time during the drawdown, uptake of bottom sediments results, pumping rates can be reduced as necessary to avoid suction and protect the water quality of Lake Apopka.

C. Holddown Phase. Lake Beauclair will be held down at 16.2 m (53.0 ft) msl for two months to allow the exposed muck bottom to consolidate. During this time, it will be necessary to operate one pump at each of the pumping stations aprpoximately four hours per day to maintain the water level at 16.2 m (53.0 ft) msl. At the end of the holddown phase, both pumping stations will be removed to facilitate the refill of Lake Beauclair.

D. Refill Phase. Refill of Lake Beauclair will be accomplished by opening the tainter gates of the Apopka-Beauclair Canal Lock and Dam. The tainter gates will be adjusted so as to control velocities in the Apopka-Beauclair Canal to minimize scouring during the refill of Lake Beauclair.

E. Cleanup. After the refill of Lake Beauclair is complete, all facilities used during the Lake Beauclair restoration will be removed. All sites will be returned to the conditions which existed prior to construction. The Lake Beauclair deep hole channel will be left as constructed. Irrigation wells will be left as constructed; pumps and motors will be removed.

Phase VIII. Post Restoration Phase.

After the refills of Lake Apopka and Lake Beauclair are completed, it will be important to monitor the water quality and bottom condition so as to evaluate the long-term changes which result from the restorations. Funding for this phase of the project is not included in the cost estimates by RSB&W (see Appendix B).

SECTION 5

IMPACTS OF PROPOSED ALTERNATIVE AND MITIGATIVE STEPS FOR IDENTIFIED ADVERSE IMPACTS

Water Quality Impacts and Mitigative Steps

The primary objective of this project is the improvement of water quality in Lake Apopka and subsequently, in the entire Oklawaha Chain of Lakes. To date, over $9 million have been spent on nutrient abatement programs in the Apopka area in an effort to stop the trend of cultural eutrophication in Lake Apopka. As a result, point source nutrient input to Lake Apopka will have been greatly reduced by the conclusion of the project. Having accomplished this, it is now appropriate to initiate a restoration project designed to undo damage caused by past nutrient inputs.

The principle behind the water quality improvement design is to reduce the recycling of nutrients in the lake. This will be accomplished by three methods: (1) The consolidation of the muck bottom will retard the exchange of nitrogen and phosphorus between the muck and water by reducing the nutrient releasing effect of sediment agitation caused by wind action and motorboat activity (Fox et al, 1977; Brezonik et al, 1978). (2) Macrophytic growth, encouraged by the reconditioned bottom and clearer water, should tie up nutrients and compete with the phytoplankton. (3) A small amount of nutrients will be exported through the increased removal of fish during drawdown. As a result of these processes, the following water quality changes can be expected in Lake Apopka within six months to five years after the completion of the project (Dawkins and Associatiates, Inc., 1975):

(1) reduction in Ortho-Phosphate, Total Phosphate and Nitrate-Nitrogen levels by about one-half of current values.
(2) reduction in the incidence of algal blooms.

(3) a shifting in the algal community away from dominance by nuisance varieties.

(4) improvement in water transparency.

As the headwaters of the Oklawaha Chain of Lakes, any improvement in the water quality of Lake Apopka will eventually be reflected in the quality of downstream waters. Restoration of Lake Apopka will prevent continuing downstream pollution caused by Lake Apopka's effluents and will allow downstream restoration to proceed on an ordered basis. However, downstream waters may suffer temporary adverse side effects during the drawdown process. Mitigative steps or corrective measures have been included in the project design for most cases where such side effects have been foreseen.

Increased Turbidity

During the process of pumping, bottom sediments could possibly be picked up with the water and exported downstream. This would increase downstream turbidity, thereby reducing downstream transparency. Avoidance of sending sediments downstream has been one of the major objectives of DER and RSB&W. Several measures have been included in the project design to prevent this adverse side effect:

(1) An adjustable weir at the south end of the Apopka-Beauclair Canal will allow only surface water to be pumped out of Lake Apopka. Surface water contains fewer suspended solids than water close to the bottom.

(2) All water leaving Lake Apopka during drawdown and holddown will pass through a 49 hectare (120 acre) in-lake sedimentation basin before continuing downstream. Constructed in the lake bottom near the south end of the Apopka-Beauclair Canal, this basin will be 885 m (2900 ft) long, 610 m (2000 ft) at its widest point, and will have a bottom elevation of 14.6 m

(48 ft) msl. The basin will have a surface loading rate of 0.031 $m^3/day/m^2$ (90 $gal/day/ft^2$) and a detention period of 20 hours. A floating hydraulic dredge will periodically pump the trapped sediments back to Lake Apopka so that they will not be resuspended in the pumped area of the lake and to allow for consolidation of the dredged sediment. While not identical to the flocculent muck, the nature of these trapped sediments is not known and it is noted that a release of nutrients may occur as the materials are agitated during dredging.

(3) The 8 km (5 mi) long, 107 m (350 ft) wide dredged channel from the deep holes in Lake Apopka to the in-lake sedimentation basin will also act as a sedimentation basin when the drawdown nears completion. It is at these lower water levels that the flocculent muck on the bottom will flow more easily and will tend to be taken up by the pumps. The channel will increase available sedimentation time and reduce the load placed upon the in-lake sedimentation basin. A hydraulic dredge will periodically pump sediments out of the channel to a point 305 to 610 m (1000 to 2000 ft) to either side of the channel. These spoils ridges, parallel to the canal, will retard the flow of flocculent muck into the canal during drawdown.

(4) Before drawdown begins, the northern portion of the Apopka-Beauclair Canal will be dredged to remove silt that might otherwise be washed downstream by the increased flow of water in the canal.

(5) Due to the nature of Lake Apopka's sediment and basin shape, local wind conditions often cause prolonged resuspension of organic solids. Ideally, pumping should be halted during these periods and continued only after the solids have resettled. However, time constraints placed upon the project by the frost/freeze concern do not allow the project design to include large blocks of time for resettling of wind-churned sediments.

Thus, in spite of the four above-mentioned steps taken to reduce the flow of turbid water downstream, unknown quantities of suspended solids may be released during drawdown. RSB&W has calculated that all suspended solids in excess of state standards, released from Lake Apopka during drawdown, will settle out in Lake Beauclair (which will have a detention time of 6 days) and will not be transmitted any further downstream. This essentially guarantees the protection of all downstream lakes, except for Lake Beauclair, which will act as a very large back-up sedimentation basin.

After Lake Apopka has been refilled, coffer dams will be built between Lake Dora and Beauclair and between Carlton and Beauclair. Lake Beauclair will then be restored via drawdown. Favorable wind conditions and reasonable rainfall during drawdown may prevent suspended solids from ever reaching Lake Beauclair. If this is the case, Lake Beauclair need not be restored. However, because of Beauclair's present degraded condition and the relative low cost of an additional drawdown at that time, RSB&W suggests that the Beauclair drawdown be carried out regardless of whether or not the Apopka drawdown causes any damage to Lake Beauclair.

(6) DER, Division of Permitting, will require the monitoring of suspended solid concentrations in water leaving Lake Beauclair during drawdown and holddown of Lake Apopka. If, at any time, the level of suspended solids exceeds state standards for Class III waters, pumping will be stopped until the situation can be corrected.

Decreased Dissolved Oxygen

Sediment usually has a high BOD and, when suspended, tends to deplete the oxygen content of water. Although the suspended sediments will not be allowed to flow downstream of Lake Beauclair, they will have an opportunity to use up the water's oxygen while in the process of settling. As a result, water leaving the Lake Beauclair basin may have a low dissolved oxygen concentration. RSB&W has indicated that in laboratory tests, Lake Apopka sediment can chemically take up a great deal of oxygen (i.e., its COD or chemical oxygen demand is high). Living organisms can also rapidly use the sediment for energy (i.e., its BOD is high). Therefore, it is likely that significant amounts of oxygen may be removed from the water during the settling process. Therefore, water leaving Lake Beauclair will be tested for dissolved oxygen concentrations and, if found to be deficient, pumping will be stopped until corrective measures are taken.

Increased Nutrient Concentrations

Since Lake Apopka is the headwaters of the Oklawaha Chain of Lakes, water being pumped downstream would follow the same route even under normal circumstances. The process of pumping during the drawdown project is not expected to increase nutrient concentrations of Lake Apopka water, thus the quality of water entering the downstream lakes will be no worse than usual in this respect. A monitoring program will indicate any nutrient concentrations in excess of state standards. If an excess is found, pumping will be halted until such time as the problem has been corrected.

Pumping, during drawdown, will decrease the time in which water flows through downstream lakes, thus reducing the interval for any time-dependent water-cleansing processes that might normally occur en route. However, during holddown, storage of water in downstream lakes increases the retention time of water in these lakes, allowing more time for macrophytes and phytoplankton to tie up nutrients and keep them in the lake ecosystem long after drawdown.

Damming of the Dead River to store water in Lake Harris for refill will reduce the amount of clean water entering downstream lakes. Thus, nutrients from Lake Apopka will not be diluted as much as they normally would be upon entering Lake Eustis and lakes further downstream.

While there are no practical mitigative steps for these last three adverse side effects, it is emphasized that most will be experienced only for a portion of the one-year duration of the project and should leave no lasting consequences. Upon completion of the project, normal flushing will again commence but with even cleaner water from a newly restored Lake Apopka.

Backflow of Low-Quality Water to Lake Harris

The hydraulics of flow in downstream lakes are such that a reversal of flow will occur in the Dead River as downstream levels are raised. This would result in a flow of lower quality water into Lake Harris from Lake Eustis and could result in the degradation of Lake Harris. To avoid this problem, a coffer dam across the Dead River adjacent to the U.S. Route 441 overpass will be provided. This dam will also serve to raise the level of Lake Harris to store additional water for the Lake Apopka refill.

Biological Impacts and Mitigative Steps

The biology of the Oklawaha Chain of Lakes will be affected directly by the physical aspects of the drawdown and indirectly by the effects of the drawdown on water quality and bottom characteristics. Some biological changes are desirable, and, in fact, achievement of these changes is the goal of the project; other changes are considered undesirable and mitigative steps will be taken wherever possible.

Flora

1. Macrophytes. Any existing rooted macrophytes in Lake Apopka will be stranded and die during the drawdown. Currently, macrophytic

growth covers only an insignificant portion (0.03 percent excluding cattails) of Lake Apopka's bottom area (FG&FWFC, 1977). Through improvement of water quality and bottom conditions, the drawdown project is expected to bring about an increase in macrophytic growth coverage, perhaps someday approaching the 62 percent coverage of pre-1946 (FG&FWFC, 1974).

No adverse effects on downstream macrophytes are foreseen. Rather, subsequent improvement of downstream waters through dilution with clean water from a restored Lake Apopka is expected to produce an increase in macrophytic growth throughout the chain of lakes.

Restoration of Lake Apopka may result in an overgrowth of some aquatic weed species, especially *Hydrilla*. This aquatic pest can grow in stands dense enough to hinder navigation. *Hydrilla* is not currently found in Lake Apopka, nor was it a problem species in the lake before its degradation. In addition, this weed is not a problem species in any of the lakes making up the Oklawaha chain. Data are currently insufficient to predict the density of *Hydrilla* in a restored Lake Apopka; however, it should be noted that *Hydrilla* is a macrophyte and performs all of the previously mentioned biological functions of macrophytes.

2. Terrestrial plants. Some vegetation growing along the shores of Lake Apopka may be stressed and die due to lack of water during drawdown and holddown. The drawdown of Lake Carlton resulted in the loss of some shoreline trees (especially red maples) with shallow root structures (Johnson, FG&FWFC, personal communication). However, area hydrology indicates that away from the immediate shoreline area, declines in the water table will be minimal (Hahn, CDM, personal communication). Furthermore, deep wells will be drilled to supply irrigation water for valuable plants (e.g. citrus trees).

Wooded swamps along the northern shore of Lake Apopka may benefit from the drawdown. Trees in this type of swamp normally live in standing water but their seeds need bare ground in order to germinate and survive. This seemingly contradictory habitat requirement is usually satisfied by natural fluctuations of the lake's water level. Since the construction of the water control structure on the A-B Canal, the water level in Apopka has not fluctuated enough to provide for germination of new trees. A drawdown may provide for a massive germination of new seedlings, some of which will survive after refill and replace older, dying trees (Best, CDM, personal communication).

3. Terrestrial weeds. During holddown, the exposed lake bottom is expected to provide a rich organic substrate for the growth of terrestrial vegetation. This growth may aid in the drying of the lake bottom through the transpiration of water via the plants' leaves; however, this could be counterbalanced by the shading effect of the plants. The plants' interweaving root systems should stabilize the muck and prevent scouring and resuspension of muck during refill. In addition, weed growth around the deep holes of water and unexposed muck during holddown will act as natural turbidity curtains during refill, restricting the movement of unconsolidated muck from the deep holes. At the same time the flooded terrestrial weeds can serve as spawning substrate, protective cover, and can concentrate fish and invertebrate fish-food organisms (Holcomb and Wegener, 1974).

Depending upon the species of weed and the length of time they are allowed to grow, some plants may reach heights of 2 to 3 m (6 to 9 ft). When the lake is refilled many of these weeds will be only partially submerged, creating an aesthetically unpleasant view. Many plants, especially cattails growing around the remaining pools of water, may become uprooted during refill and form unsightly mats of floating vegetation on the surface of the lake. Those that remain rooted may compete with or reduce the successful growth of other aquatic vegetation. As the terrestrial plants die and decompose, they will release their nutrients back to the water recreating water quality problems and algal blooms. However, populations of macroinvertebrates, feeding on the dead weeds, will increase dramatically if not restricted by low oxygen concentrations on the bottom. (Mixing of the water by wind action should supply bottom waters with sufficient oxygen.) As a result, bottom-feeding fish (e.g., catfish), preying upon macroinvertebrates, will likewise increase in population size. In 1975, before its drawdown, Lake Carlton had an estimated 4.41 kg/hectare (24 lb/acre) of catfish in its littoral zone;

in 1978, shortly after its drawdown, this figure had jumped to 65.71 kg/hectare (358 lb/acre) (Johnson, FG&FWFC, personal communication).

Weeds will be permitted to grow undaunted on the exposed lake bottom in order to reap the potential benefits of the terrestrial vegetation and because there is no proven safe method of stopping its growth. To avoid the consequent release of nutrients and the unsightly appearance of emergent weeds, the weed growth could be selectively harvested before refill. In near shore areas where the muck layer is thin and underlain by sand, and where weed growth is most extensive due to the longer exposure of the bottom, traditional weed harvesting equipment may be used. In areas where the muck has not consolidated enough to support the weight of moving equipment, the weeds could be removed by aquatic weed harvesters after refill has partially flooded the weeds. Nevertheless, a ring of weeds should be left around the pools of unconsolidated muck to act as a turbidity barrier. It should be pointed out, however, that the loss of nutrients due to weed harvesting would probably not be significant in terms of the entire ecosystem.

As outlined in Table 5.1, there are reasons both for removing the terrestrial weeds and for leaving them. In this situation, one aspect overrides all others; the estimated cost of weed harvesting is in excess of $10,000,000 (RSB&W, personal communication). Thus, the cost of weed harvesting would make the project economically infeasible while providing somewhat dubious benefits.

4. Phytoplankton. One of the primary objectives of this project is to reduce the phytoplankton population of Lake Apopka. This can be accomplished by reducing the nutrient content of the lake's water, and by increasing the number of macrophytes that can compete with phytoplankton for the remaining nutrients. Furthermore, the reduced nutrients should shift the phytoplankton populations away from predominantly blue-green species to less noxious green species.

Table 5.1. Pros and Cons of Terrestrial Weed Removal.

Pros:

(a) Weed harvesting represents the removal of biomass and nutrients from the lake. (However, the loss of nutrients would probably not be significant in terms of the entire system.)

(b) Weed removal would reduce aesthetic problems and public complaints.

(c) Odor problems from decaying vegetation following reflooding would be reduced.

(d) Weed growth may shade the exposed lake bottom and retard drying and consolidation of the muck.

(e) Terrestrial plants may compete with or reduce success of aquatic vegetation upon reflooding.

(f) Decomposition of dead terrestrial weeds after refill could bring about oxygen depletion and nutrient release with subsequent algal blooms.

Cons:

(a) Based on available literature, weed removal for a lake as large as Lake Apopka could easily exceed $10,000,000.

(b) Severe problems may be experienced in disposing of the huge volume of plant material harvested.

(c) The logistics of working in the muck are quite difficult. Conventional, terrestrial machinery probably could not be used; expensive machinery would be necessary.

(d) The weeds will provide a temporary habitat for key aquatic organisms; one goal of the project is to create such habitats.

(e) The root systems of weeds will stabilize the muck and prevent scouring and resuspension of muck during refill.

(f) Weed growth around pools of unconsolidated muck will act as turbidity curtains during refill.

(g) Weed growth could aid in drying the sediment through the transpiration of water via the plants' leaves.

Downstream phytoplankton populations may temporarily increase as nutrient-rich Apopka water is pumped through the chain of lakes. However, DER, Division of Environmental Permitting, requires that water pumped into downstream lakes be tested for phosphorus and nitrogen content, and that this water not exceed standards established in Chapter 17-3, Florida Administrative Code.

5. Bacteria. Fecal coliform bacteria, derived from the intestines of warm-blooded animals, cannot reproduce or survive long in water; therefore, fecal coliform from Lake Apopka will have no impact on downstream lakes. Soil coliform bacteria (a component of total coliform counts) can survive and reproduce in water. These bacteria will be carried downstream with pumped Apopka water, as they are under normal discharge conditions. The total coliform counts in Lake Apopka are generally within the standards set by Chapter 17-3, Florida Administrative Code, and the pumping of Apopka's water into downstream lakes is not expected to affect the bacteria counts of the receiving waters.

Fauna

During drawdown animals may be adversely affected in a variety of ways:

1. Aquatic animals may be stranded in shallow pools and die as the water evaporates around them.
2. Animals may temporarily lose their feeding habitat and have a more limited source of food during the project.
3. Animals may temporarily lose their reproductive habitat and fail to reproduce during the project.
4. Animals may be stressed or die due to low oxygen levels.
5. Filter-feeding animals may be stressed if their feeding mechanisms are clogged with increased suspended solids.
6. Small animals may be washed away by the increased flow.
7. Benthic animals may be buried with increased deposition of suspended solids.

For a variety of reasons, some animals will die or fail to reproduce during the drawdown project. With the exception of the rare or endangered species (discussed below) the animals of the Oklawaha Chain may be thought of as a renewable resource. Animals that die during the project will be replaced through reproduction of the survivors after the project is completed.

One of the objectives of the drawdown project is a shift from the present rough fish population towards a game fish population. Much of Apopka's current fish population is expected to die when the drawdown concentrates them in too small an area for sufficient oxygen to exchange across the water surface. To avoid the release of nutrients from the decomposing fish and to avoid the waste of a natural resource, rough fish could be harvested before or during drawdown. The dense concentration of fish during drawdown is expected to attract commercial fishermen who, in past drawdowns on other lakes, have found ways of crossing the mud flats to reach the pools of water (Holcomb, FG&FWFC, personal communication). One possible design includes a dredged channel from the Montverde boat ramp to the deep holes of Lake Apopka; this would make the concentrated fish easily accessible to commercial fishermen. In addition, many of the dead fish will be eaten by birds, alligators, turtles, and terrestrial mammals. This will further contribute to a net export of nutrients from the lake.

In downstream lakes there is a danger of fish kills caused by the pumping of oxygen-poor water from Apopka. The high concentration of fish during drawdown may deplete the water of its oxygen. In addition, the BOD of the suspended solids in the in-lake sedimentation basin and in Lake Beauclair may further reduce the dissolved oxygen concentration of water entering the rest of the chain of lakes. However, tests by RSB&W (Ramsey, personal communication) have indicated that the BOD of Lake Apopka's sediment is relatively low; therefore, oxygen depletion may not be a great problem during drawdown. Furthermore, during drawdown, water entering downstream lakes from Apopka will be tested for oxygen content, and pumping will be stopped if insufficient oxygen is present. Even though fish are considered a renewable resource, it is again stressed that every effort will be made to avoid a downstream fish kill. The effects of such a fish kill are temporary and may be unavoidable during the improvement of Lake Apopka and downstream lakes.

The consolidated lake bottom will provide breeding areas for game fish. Sand, dredged from the 6.4 km-long channel and from the in-lake sedimentation basin, will be spread over the surrounding muck to further improve conditions for game fish breeding. Similar spoils areas in Lake Carlton have proven to be regions of best survival for new macrophytic growth (Johnson, FG&FWFC, personal communication). The expanded littoral zone will provide protective areas for young game fish to grow and for fish food organisms to multiply. Improved water quality will recreate conditions favorable to game fish and aid in the shifting of the fish community away from a predominantly rough fish population. While most of the biological benefits of a successful restoration will be felt in Lake Apopka, some of the effects will extend throughout the chain of lakes as downstream water quality improves due to the diluting effects of cleaner effluent from Lake Apopka.

Endangered Species

The Biology section lists 21 endangered, threatened, rare or special concern species in the Oklawaha Chain of Lakes. Six of these species are potentially dependent on Lake Apopka.

A. Lake Eustis pupfish (*Cyprinodon variegatus hubbsi*). This fish reaches a maximum size of 5 cm (2 in.) and lives in very shallow water in areas with a sandy bottom and no vegetation. These fish are found only in Lakes Harris, Beauclair, Dora, Carlton, Eustis, Griffin, Yale and Lake Weir. The Lake Eustis pupfish has never been found in Lake Apopka.

It is believed that the population size of this species has increased greatly since it was first discovered in 1939, leading naturalists to theorize that the fish are well-adapted to the increasing human influence.

Before its 1977 drawdown, Lake Carlton supported very few pupfish, yet shortly after refill, the lake supported many of these animals (Johnson, FG&FWFC, personal communication).

Since there are no Lake Eustis pupfish in Lake Apopka, the drawdown project will not directly affect this threatened animal. Because the fish live in very shallow water, close to the shore, the increased flow of water in downstream lakes during the drawdown will not affect the downstream populations of pupfish. In the opinion of Bill Johnson of FG&FWFC, a recognized authority on the Lake Eustis pupfish, this fish will not be adversely affected by a Lake Apopka drawdown. He further states that the restoration of Lake Apopka may provide a new area of expansion for the species.

B. Alligator (*Alligator mississipiensis*). Alligator populations in the United States have increased to such an extent over recent years that the federal government has changed the designation of the alligator from endangered species to threatened species. The great increase in the number of alligators in Florida has led to the hiring of special trappers to remove or kill alligators specified as "dangerous" to humans. Although a census has not been taken on Lake Apopka, Tommy Hines, a FG&FWFC authority on alligators, estimates that the alligator density of Lake Apopka equals that of Lake Griffin (43 alligators per km of shoreline).

A 1971 gravity drawdown of Lake Apopka was terminated when an unusual number of alligators were found dead. Although *Aeromonas* infection is thought by many to have been the cause of death, this has never been verified and the alligator kill may merely be coincidental with the drawdown. Mr. Hines notes that drawdowns on Lakes Griffin, Trafford and Carlton did not affect their sizeable alligator populations.

In Lake Apopka, however, the alligator population will be affected by the proposed project. As the lake level recedes, some alligators may migrate to neighboring bodies of water. Since the area around Lake Apopka is relatively unpopulated, the number of alligator/human contacts should be small during the migration. In addition, the holddown period (June and July) occurs during the alligator nesting time. This will result in a reduced hatch and may even cause the loss of an entire year's brood for those alligators remaining in Lake Apopka. Mr. Hines points out, however, that this would not greatly affect the size of the alligator population since the reproductive members will still live to reproduce the next year.

C. Florida water rat or round-tailed muskrat (Neofiber alleni). According to Chris Belden, FG&FWFC mammalogist, this muskrat is dependent upon aquatic and semi-aquatic vegetation (especially maidencane) for its food and lodging. Although a muskrat census has not been taken on Lake Apopka, it would be expected that few, if any, muskrats presently inhabit the lake due to the notable lack of vegetation.

Downstream lakes, with considerably more vegetation, should support a muskrat population. Mr. Belden believes that any rise in downstream water level due to the Apopka drawdown should not affect the muskrats since they are often found in water up to 10 ft deep. He further notes that after the 1977 drawdown and refill of Lake Carlton, evidence of muskrats "became more obvious" in the lake's new weed growth.

D. Wood stork (Mycteria americana), bald eagle (Halicetus leucocephalus) and osprey (Pandiou haliaetus). None of these fish-eating birds will be nesting during the June-July holddown. Therefore, they will not be confined to the Apopka area should their supply of fish be reduced or eliminated during drawdown. The birds will be nesting from January to May, the drawdown period. As water is pumped out of the lake, the fish will become more concentrated in the remaining shallower water, making them more available to the birds. As a result, the nesting birds should benefit from the increased availability of food. During the drawdown period there may be a temporary influx of these birds from other areas (especially the wood stork colony at Lake Yale) taking advantage of the abundant food supply. Lovett Williams (FG&FWFC, Wildlife Research Office) has indicated that, in general, these birds will benefit from the Lake Apopka drawdown and should experience no adverse impacts. During a 1973 drawdown of Conservation Area 2A (Broward and Palm Beach counties) biologists noted that wading and fish-eating bird populations increased greatly due to the enormous supply of fish. In addition, the birds (including the osprey and bald eagle) were not harmed by eating fish that were killed during the drawdown (Dineed, 1974).

Human Health Hazards

1. Virus. Despite the fact that sewage effluent to Lake Apopka will have been stopped before the pumped drawdown begins, there will probably be viruses left from previous sewage effluents in the sediment of the lake. These residual viruses will die over a period of time, but the amount of time needed is unknown. Since lakes in the chain receiving the drawdown waters are not used as a potable water source, resuspended virus-containing sediments should pose no real health problem in that (1) the level of viruses surviving in the sediments should be extremely low, and (2) these solids would tend to settle out during sedimentation. (Wellings, Epidemiology Research Center (ERC), personal communication).

"Unless these drawdown waters will be used as a raw water source and/or man would be exposed through water contact sports, I do not feel that viruses *per se* would pose a health hazard in the drawdown procedure." (Wellings, ERC, personal communication).

Swimming and water skiing, while permitted, are not currently practiced on Lake Apopka due to the aesthetic unpleasantness of the water. During the drawdown and holddown, the water quality in the lake will likely be worse than it is now due to higher temperatures and increased turbidity. In addition, anyone wishing to reach the remaining pools of water will have to cross up to 4 km (2.5 mi) of mud flats. As a result, no body contact with Lake Apopka water is expected during the drawdown project. Nevertheless, Lake and Orange Counties should post the lake to warn visitors of possible danger.

2. *Aeromonas*. Personnel from the Epidemiology Research Center have found *Aeromonas* in Lake Apopka, with higher counts at sites receiving

citrus wastes. However, Aeromonas has been found in virtually all Florida lakes that have been tested. Personnel from the Florida Department of Health concluded that the threat of Aeromonas to human health is negligible. Aeromonas infection in humans is extremely rare and apparently occurs only after the human host has already been weakened by debilitation, disease or injury. They further concluded that the water of Lake Apopka was no more threatening to human health than was water from numerous other lakes in Florida.

3. Naegleria. Tests on Lake Apopka in September, 1977, indicated the presence of Naegleria, the causative agent of primary amoebic miningoencephalitis. This relatively rare disease occurs when the pathogenic amoeba enters the nasal tissue of a swimmer diving close to the bottom of a heavily sedimented body of water. A drawdown may concentrate these amoebae since the highest populations are usually found in, or just above, the lake water sediments.

These amoebae prefer a higher temperature (29°-36°C) for reproduction than do many other organisms and they feed on bacteria. Therefore, a drawdown, resulting in increased water temperatures and increased concentration of decay bacteria, would favor the reproduction of pathogenic Naegleria. "If swimming and/or water skiing were not permitted on Lake Apopka during the actual low level period, there should be no health problems encountered due to pathogenic Naegleria. Once the lake water level is increased, the dilution effect and decrease in temperature would once again offer protection." (Wellings, ERC, personal communication).

Since Naegleria live in the sediment, these amoebae will not be present in the water pumped from the surface of Lake Apopka. Any Naegleria suspended in the pumped effluent will settle out during sedimentation before the water is discharged beyond Lake Beauclair. Thus, concentrations of Naegleria, downstream of Lake Beauclair, should not be increased due to recruitment from Apopka, but will actually decrease due to the dilution effect of the addition of Lake Apopka water.

4. Mosquitos. The drawdown of Lake Apopka is expected to provide numerous temporary sites for mosquito breeding. As the exposed lake bottom dries it will form deep cracks that will fill with rain water.

Mosquitos will lay their eggs in this standing water and the larvae will live there until they emerge as adults. The water-filled cracks will not contain any predators that might control the mosquito population.

Besides being an annoying pest, the female mosquito may also be a carrier of diseases. Mosquitos normally sip plant nectar as a food; however, female mosquitos need a meal of blood in order to obtain enough protein to form eggs. This blood meal normally comes from a warm-blooded animal (bird or mammal). Various species of mosquitos may carry different diseases. One species from central Florida, *Culex nigripalpus*, can carry a virus that causes a human disease known as St. Louis encephalitis (SLE), a disease of the protective layer covering the central nervous system. A female mosquito of this species, biting an infected mammal or bird, picks up the virus with the blood. The virus incubates and multiplies in her body, and, when she bites again, some of the virus are injected into the new host.

In 1977 the first cases of SLE were reported in central Florida since 1962. Two cases were reported in northern Lake County and 15 cases in Orange County (Buchanan, Lake County Mosquito Control Department, personal communication). The disease seems to occur sporadically although the disease-carrying mosquito is found every year.

Previous drawdowns have had varying degrees of mosquito problems. Both Alexander and Buchanan (Orange County and Lake County Mosquito Control Departments, respectively) indicated that the mosquito problem around Lake Carlton was quite severe during its recent drawdown. Populated areas around the lake were sprayed to control adult mosquitos at weekly intervals; however, Mr. Alexander feels that the problem remained severe enough to warrant twice weekly sprayings. The mosquitos emerging from Lake Carlton at that time were not the virus-carrying *Culex nigripalpus*, but belonged to a group of species known collectively as floodwater mosquitos. These mosquitos do not carry disease but do bite humans.

According to Reeves and Wilson (Osceola County and Polk County Mosquito Control Departments, respectively) the drawdown of Lakes Tohopekaliga and Kissimmee created no mosquito problem at all, and in fact, may have alleviated some existing mosquito problems. The drawdown of these two lakes exposed mostly a sandy shore and very little muck; therefore, very few cracks formed to serve as mosquito breeding areas.

No increased mosquito complaints were noted during the Lake Munson drawdown (Boyd, Leon County Mosquito Control Department, personal communication). However, Mr. Boyd notes that the mosquito complaints are normally very numerous around the heavily populated Lake Munson area. Therefore, spraying for adult mosquitos usually occurs twice weekly in this area.

Portions of the muck farms north of Lake Apopka are flooded periodically to control parasitic worms in the soil. During this flooding there is usually a problem of mosquito control. Decaying plant stalks left in the fields condition the floodwater so as to favor the growth of *Culex nigripalpus*. In August, 1978, surveys by the Orange County Mosquito Control Department indicated that a large population of this virus carrier was present in the flooded fields. During this period the fields were sprayed for adults and larvae at weekly intervals.

The Lake Apopka drawdown period is not expected to promote a population increase of *Culex nigripalpus* but will most likely increase the number of floodwater mosquitos. The flooded terrestrial vegetation during refill could promote *Culex nigripalpus*, but the small fish remaining in Lake Apopka may be able to control the mosquito population through predation upon the mosquito larvae. Prevailing summer winds tend to blow mosquitos away from the populated areas south of the lake towards the muck farms. Nevertheless, Orange County and Lake County Mosquito Control Departments spray the Lake Apopka area weekly for adult mosquitos, hold regular inspections to determine the predominant mosquito species, and survey bird populations for the occurrence of SLE virus during the mosquito season.

The downstream effects of drawdown will not require mosquito control measures and may even reduce mosquito populations. Flooding of low-lying swamp areas along downstream lakes during drawdown and holddown may allow the invasion of small fish which prey upon mosquito larvae.

Physical and Socioeconomic Impacts and Mitigative Steps

Topography

Topography will be altered only in the immediate vicinity of the lakes affected by the drawdown. Slight changes in elevations will occur as dike levels are raised and dredged spoils accumulate, but these changes are minor in scale and void of negative consequences. Construction sites will be restored after the drawdown; therefore, no adverse topographic effects are expected.

As lake bottom sediments consolidate during drawdown, Lake Apopka will become deeper and increase in volume by approximately 13 percent (Schmertmann, 1978). Additional changes in morphometry will result from the excavation of the sedimentation basin, sumps, and related channels and canals in several of the lake bottoms and from silt removal in the Apopka-Beauclair Canal. These changes should also have no significant effects, because all excavations except the sedimentation basin are shallow, and future shifting of bottom sediments will eventually refill the channels. The sedimentation basin will remain as part of the restored Lake Apopka.

Soils

Potential effects on soils would result almost exclusively from the accumulated dredged spoils of the pump sumps and the proposed construction sites. Unless adequate preventative measures are taken, dredged spoils could return to the lakes via erosion, increasing turbidity and decreasing water quality. Dredged materials retained on upland areas will also require drying before constructive use can be made of them.

Spoils from the 6.4 km (4 mi) long underwater channel in Lake Apopka and from periodic dredging of the in-lake sedimentation basin will be returned to the lake bed. The remaining sumps and channels, however, will require spoil sites, some of which may remain even after cleanup operations are completed. These spoils should be physically contained to prevent erosion. Encouraging vegetative growth on the spoils would also reduce erosion and complement the restoration's objective of improving water quality. Since construction activities and the location of spoil sites must comply with permitting standards of DER, no significant adverse impacts are expected.

Soils exposed or disrupted by construction of pumping stations on downstream lakes (see Figure 4.1) should also be protected from erosion. Since these sites must be restored upon project completion the topsoil and dredged spoils should be saved and utilized as necessary to attain pre-drawdown conditions. Normal plant growth will stabilize these soils and negate any long-term erosional problems. If control measures are practiced during construction and restoration of the pumping sites, no significant adverse soil erosion is expected.

Air Quality

Short-term. Construction equipment, dredging machinery, and pumps will be the major sources of increased emissions during the restoration project. No significant adverse effects are expected as a result of these sources because the pollutants will be quite dispersed and emitted in relatively low quantities. Specific estimates of emissions are not possible, however, until the quantities and types of equipment are specified.

Long-term. A secondary air quality impact will occur after the lake restoration project is completed. This impact is associated with future vehicular traffic densities in the lake vicinity. A restored Lake Apopka will experience an increase in recreational opportunities and will attract numerous residents and tourists. The increase in traffic associated with these recreationists, however, is not expected to degrade the area's air quality to any great extent.

Odor

Increased nutrient concentrations and possible related plankton blooms could lead to an odor problem in downstream lakes during drawdown (Olsen and French, 1976). If a significant sag in oxygen levels occurs, fish kills could add to this odor. In addition, certain blue-green algae, windrows of exposed water plants, and other decaying organic matter would emit noxious odors. Should these adverse effects occur, however, they will be temporary and will cause no long-lasting downstream odor problems (Hahn, 1978).

Lake Apopka will experience more severe odors than the downstream lakes, although the extent of such odors is presently unknown. No lakes with the same physical attributes as Apopka have been drawn down; therefore, the actual intensities of any odors during the drawdown are speculative. For example, the Lake Carlton drawdown resulted in no major odor problem and few complaints, if any, were expressed by adjacent landowners (Holcomb, FG&FWFC, personal communication). Lake Apopka, however, is much larger and could experience such a problem. The major sources of noxious odors would be the remaining pools of nutrient-rich water, decaying organic matter, and the exposed muck sediments on the lake bottom. As shad become concentrated in the remaining pools of water during the drawdown, heavy fish kills are expected (Hahn, 1978). If these fish are removed prior to or during drawdown a definite source of odors will be eliminated. As in the downstream lakes, any odor problem in and around Lake Apopka will be temporary.

Several factors will mitigate the adverse effects of a potential odor problem in Lake Apopka. The prevailing wind direction during the drawdown/holddown period is from the southeast; therefore, disagreeable odors will travel away from residential communities on the south shores of the lake. Before the odors reach any developed areas to the northwest of the lake, they must travel over farmlands and citrus groves. These vegetated buffer areas in conjunction with the dispersal action of the wind should mitigate any significant adverse odors, although some residents will inevitably encounter disagreeable odors. The vegetation which will flourish on the exposed lake bottom may also diminish odor effects by utilizing decaying organic matter and providing a buffer between the exposed lake bottom and nearby inhabitants.

A successful lake restoration will deter the periodic fish kills and continuous plankton blooms that presently cause odor problems in Lake Apopka. In effect, a more intense odor problem during the drawdown will be exchanged for greatly reduced odors following restoration.

Noise

Short-term. Noise pollution will result from the restoration project because of the required construction work. Trucks, dredging equipment, pumps, and other heavy machinery will contribute the majority of this noise; however, the pumps are the only equipment which will operate throughout the project. Most of the other machinery will be used only during pre-drawdown construction or post-refill clean-up operations.

The major impact of noise will be in Tavares on land adjacent to the Dora Canal bypass pipeline. Because Tavares is an urban area and heavy construction is associated with the canal bypass, more noise will be perceived in this area than at any of the other construction sites. The other construction sites are relatively isolated and will not require extensive excavation or relocation of underground utilities; therefore, construction activity at these sites will be less pronounced.

To mitigate the most severe noise impacts, electrical pumps will be installed at the Dora Canal pumping site. These pumps are relatively quiet and should cause little irritation to nearby residents. Cheaper, yet much louder diesel pumps will be installed at the other pumping sites. Since these sites are basically rural and isolated, no significant noise impacts are expected. Impacts during installation of the Dora Canal bypass pipeline could be mitigated slightly by restricting construction hours to a reasonable daily limit. This would not decrease the total amount of noise generated, but would avert some conflicts with residents. Overall increased noise is a temporary inconvenience that is associated with any job requiring heavy machinery.

Long-term. Increased recreational use of Lake Apopka would result in higher noise levels due to automobiles, motor boats, and crowds. Traffic both in and around the lake will increase, and congestion of the area can be expected, as with any heavily used recreation site. The extent of increase in ambient noise levels will depend on the amount of use the lake receives and is impossible to assess in this study. The size of the lake and the long distances between access points, however, indicate that future noise levels should be no worse than those of other water-based recreation sites.

Historical/Archeological Resources

As required by the National Historic Preservation Act of 1966 (Public Law 89-665), potential impacts of the restoration project upon historical and archeological resources must be evaluated. As previously explained in the "Existing Conditions" section, no inventory of potential sites for the National Register of Historic Places currently exists for the study area. A comprehensive survey must therefore be conducted on all sites which will be physically affected or altered during construction procedures. This site specific investigation must be conducted prior to construction and should concentrate on the proposed construction sites, spoil disposal sites, pump and pipeline locations, and access roads. This survey is now in its preliminary planning stages and will be supervised by the Florida Department of State, Division of Archives, upon approval of the drawdown project.

The completed survey report must be submitted to the Florida State Historic Preservation Officer for review and acceptance. If historical or archeological resources are located on construction sites, mitigating measures for the removal or protection of these artifacts must be adopted and implemented. The inventory should therefore be completed as early as possible to prevent delays in the restoration project. Because these procedures are required by law, no adverse impacts should occur to any newly discovered historical or archeological resources.

Aesthetics

Not all benefits or adverse impacts of a project are related to physical, quantifiable factors. The aesthetic perception of a resource, for example, although difficult to quantify and impossible to define in a monetary sense, is a valid consideration.

Short-term. Many conditions during the drawdown and holddown stages of the restoration project will be aesthetically unappealing. Fish kills, decaying biomass, windrows of aquatic plants, exposed muck sediments, and plankton blooms will occur during the project and will not be pleasant from a visual or olfactory perspective. These impacts are temporary, however, and will be eliminated upon refill. In addition, growth of vegetation on the exposed lake bottom may mitigate these impacts to a certain degree. During refill possible uprooting of terrestrial vegetation could be aesthetically unappealing as the floating vegetation would be blown towards the shoreline.

Long-term. A successful restoration project will improve the water quality of Lake Apopka and will have subsequent beneficial effects on recreation, fishing, and the general physical and biological condition of the lake. This improvement, therefore, will tremendously increase the aesthetic appeal of the lake and its surrounding area. Lake Apopka in its current condition is unappealing to most people, as witnessed by the lack of recreationists. Even though the lake's waters are biologically suitable for water contact sports, few people indulge in these activities. The restoration project, by improving the aesthetic appeal of the lake, will ensure future recreational use of Lake Apopka. These benefits should also extend to downstream lakes as water quality gradually improves.

Population Growth

A drawdown and successful restoration of Lake Apopka should not affect long-term population growth rates in the project area. In-migration of middle and upper age residents will continue to account for the major proportion of the population growth and the number of retirees will continue to rise. While some in-migrants may move to the area because of a restored Lake Apopka, overall population growth will probably continue in its present fashion. New residents generally relocate because they are interested in the region as a whole rather than in one specific natural resource.

Geology

The water table in the area around Lake Apopka will lower as the lake is drawn down. Prickett, a CDM hydrologist, states that the areas in which the water table aquifer will be measurably affected (greater than 0.03 m (0.1 ft) decline from the "normal" water table surface) were estimated to extend landward from the lake about 3.2 km (2 mi) to the south, about 2.4 km (1.5 mi) to the east and west, and about 1.6 km (1 mi) to the north. Drops in the water table of up to 2.7 m (9.0 ft) can be expected at lakeside. Most wells in this area are much deeper than the expected decline and would not be affected by this lower water table; therefore, no significant adverse effects are expected.

The drawdown may affect those residents or farmers who depend upon non-artesian wells for part of their freshwater supply. The extent of impacts upon these wells will vary according to the depth of the wells, proximity to the lake, and pumpage rates. Supplemental water will be supplied to those residents who are adversely affected by the lower water table. This impact will be eliminated once the lake is refilled and the water table returns to its former level.

The Floridan Aquifer will also be influenced by the restoration project. As Lake Apopka is lowered, Gourd Neck Springs will increase its flow rate, resulting in an incremental drawdown of the Floridan Aquifer's potentiometric* surface. RSB&W estimates that the maximum decline in the Floridan Aquifer's potentiometric surface will be 2.7 m (9.0 ft) at the springs and 1.1 m (3.6 ft) approximately 1.6 km (1 mi) from the springs. Measurable declines (greater than 0.03 m) will extend roughly 12.9 km (8 mi) in all directions from the springs' center.

Presently, the Floridan Aquifer potentiometric surface is above lake level in the south, and below lake level in the north. As the lake level declines, the differential in heads between the lake and the Floridan Aquifer will increase to a maximum of 2.7 m (9.0 ft), causing an upward flow into the lake. The upward leakage is estimated to be about 7570 m^3/day (2 million gal/day), and will lower Floridan Aquifer water levels as far as 4.8 km (3 mi) landward from the lake. This leakage effect is smaller than that due to increased flow from the above mentioned spring.

Considering the productivity of the Floridan Aquifer in this area, no shortage of water is foreseen. The only expected impact is the slightly increased pumping head needed to compensate for the depressed potentiometric surface near the spring.

Land Use

Short-term. An extreme drawdown could have severe effects on agricultural lands around Lake Apopka if certain engineering constraints were not mandated. The muck farms to the north of the lake must have sufficient water to irrigate and flood their fields as necessary, to maintain productivity during the drawdown. During the rainy season these same fields must be drained of excess water to prevent flood damage to crops. Lakeside citrus orchards also have certain irrigation requirements which must be maintained. These irrigation, flooding, and drainage problems, however, have been adequately addressed by the engineering firm (see section entitled Description of Selected Alternative). Since these requirements of the agricultural industry will be met through engineering designs, no adverse agricultural effects are expected during the project.

Another drawdown-related impact concerns possible frost/freeze damage to citrus groves on the southern shores of Lake Apopka. If the lake were to remain drained during the winter season, the warming effect of the lake on adjacent, downwind citrus groves would be forfeited (Bartholic and Bill, 1977). To mitigate this effect the engineering firm has manipulated the drawdown schedule to an agreeable format. This solution will substantially reduce the possibility of frost/freeze damage; therefore, no adverse effects are expected. Further analysis of this problem is detailed in the following section entitled Meteorological Impacts.

The drawdown plan requires local changes in land cover at all pumping stations (Figure 4.1). Access roads, parking areas, fuel storage and trailers will be installed at these sites and will preempt the present use of the land. Certain amounts of soil erosion can be expected during the construction and dismantling of these stations, temporarily increasing turbidity levels in the adjacent waters. Further pollutants could result from oil, grease, and fuel being carried into the lakes via runoff from the parking areas and pump engines. These pollutants can be contained through simple physical barriers (e.g. straw bales), therefore, negative impacts should be minimal.

Long-term. Although the restoration is not expected to alter the population growth rate of the area, it may affect the spatial distribution of residents. Water bodies, especially lakes, attract residential developments; however, the attraction of a lake is affected by its perceived water quality (Tihansky, 1975). A restored Lake Apopka will have better water quality and may experience an increased demand for lakeside development. Two possibly adverse effects could result from such a demand: (1) urban encroachment on lakeside citrus groves may increase, and (2) uncontrolled lakeside development could affect the future water quality of the lake.

Expansion of residential or commercial development towards lakefront properties would eventually conflict with the current citrus agricultural lands. Such a conflict would accelerate the rate at which orchards are being replaced by urban development. This is in direct contrast to the local comprehensive development plans which promote the protection and conservation of agricultural lands (LCPD, 1977a). Citrus orchards are not only the major economic resource of the area but are important recharge areas for the Floridan Aquifer. These agricultural lands also double as desirable open space and act as a buffer zone around the lakes.

If residential areas were developed in accordance with the Lake County Urban Containment Policy, lakeside citrus orchards would receive more protection. Inevitable urban encroachment on the groves could be directed towards areas where freeze damage is most common and dangerous, thus protecting the highly productive orchards. Therefore, even though grove acreage would decline, production per acre and total production would remain stable or increase (IFAS, 1973).

Development of lakeside property can also result in increased runoff and soil erosion from additional impermeable surfaces such as roofs, driveways, and roads. The actual construction of lakefront residences intensifies soil erosion, with a related rise in turbidity levels in adjacent lakes. Septic tanks can further increase nutrient loadings into the lake. In 1972, domestic sources contributed approximately 62 kg (137 lb) of N and 93 kg (205 lb) of P per day to Lake Apopka (Florida DPC, 1972). Cultural development, therefore, can damage a lake's attractiveness as a natural resource if lakeside growth is not carefully regulated.

It must be emphasized that these long-term land use effects are secondary, indirect problems that could occur if sufficient regulatory action is not taken. The actual restoration of Lake Apopka complements both the Lake County Comprehensive Plan (1978) and the Northwest Orange County Growth Management Policy (1977). These plans support the preservation and enhancement of natural resources and environmentally sensitive areas such as Lake Apopka (Orange County Planning Department (OCPD), 1977).

The 1977 Conservation Element (draft) for Lake County further supports the planning and location of urban growth to avoid destruction of the region's unique natural features, such as lakes and prime agricultural land. The Land Use Element favors a lakeshore development policy to enhance the natural character of these resources. If these policies are promoted and implemented, growth around a restored Lake Apopka would not degrade the lake's waters. The major effort to mitigate these potential long-range impacts, therefore, is control of lakeside development through land use policies. It is only through a complementary program of lake restoration and intelligent subsequent development that Lake Apopka will regain its status as a valuable natural resource.

Environmentally conscious development is thus quite desirable for the Lake Apopka watershed. Utilization of land use controls such as zoning and soil erosion ordinances can reduce the negative impacts commonly associated with lakeside residential development. Soil erosion can be controlled through vegetative and mechanical means while an analysis of soil qualities can determine which areas are suitable for septic tank systems. Measures should also be taken to limit stormwater runoff to pre-development levels since precipitation alone accounts for forty percent of the N and thirty percent of the P entering Lake Apopka (Brezonik, 1978).

Another potential land use problem concerns water storage in downstream lakes. Project-related water levels in these lakes will not exceed the maximum operating levels enforced by the SJRWMD (See Table 2.6); however, the potential for flooding exists. If a hurricane, or other disaster greatly increased water input to the chain during the proposed high water levels, flooding would occur. This impact would damage low-lying waterfront property, especially along the Dora Canal where many mobile homes lie only a foot or two above present water levels. In addition, several dikes will be modified to handle the increased flow of water during the project. These higher dike levels and their related increased volume flows raise the disaster potential should a dike fail and cause flooding.

Flooding impacts should not occur; however, the potential for such a problem must be recognized. To reduce potential flood damage, weather forecasts should be continually monitored so that advance warnings of severe storms or hurricanes could be directed to the pump operators and lakeside residents. If a hurricane does strike the area, substantial flooding could not be prevented; however, the lakes could be drained as much as possible to reduce damages.

Modified dikes will be inspected periodically and necessary repairs will be implemented to ensure the safety and stability of these structures If any signs of dike failure are observed or if the dikes are at any time threatened by high water levels, steps will be taken immediately to correct the situation. Such precautionary measures will mitigate most problems that could arise. Some areas may experience localized flooding due to wind-driven waves, but these problems will be solved as they become apparent.

Environmentally Sensitive Areas

Since the restoration project predominantly involves moving water through established channels, little impact is expected on most of the lakes' environmentally sensitive areas. Wetlands adjacent to Lake Apopka will experience low water conditions while downstream areas are flooded, but such fluctuations are not harmful to wetlands. Flood plains, wetlands, and similar lands retain water and slowly release it during droughts or simulated dry periods such as the drawdown (ECFRPC, 1972b). The drawdown will be a quasi-natural fluctuation in water levels and of no detrimental effect to the wetlands.

Although fluctuating water levels will not harm the areas, installation of pumps, access roads, and other equipment could be damaging. To mitigate such impacts, care should be taken to minimize the destruction of affected wetlands during construction and restoration. Environmentally sensitive areas should not be used for dredged spoils deposition if at all possible, or be subject to other actions which may preclude their future natural functions.

The Dora Canal by-pass pipeline will be constructed to eliminate adverse effects in the Dora Canal cypress swamp. Similar actions should be encouraged to protect other sensitive areas. These lands are important for their biological productivity, water recharge characteristics, and nutrient assimilation capabilities. If these areas are deprived of their natural functions, water quality will degrade accordingly as fewer nutrients are absorbed. Again, construction work and spoils deposition must comply with Department of Environmental Regulation permitting standards; therefore, adverse impacts should be minimal.

One adverse impact that will occur involves the removal of vegetation from a small (roughly 23 m by 53 m) parcel of wetlands at the south end of the Apopka Beauclair Canal. This area will then be dredged to an elevation of 16 m (53 ft) msl with the spoils being deposited on adjacent ground. The removal of this wetland is necessary to attain adequate flow through the canal during drawdown. Upon completion of the project the spoils are to be replaced and revegetated; therefore, the negative impacts will be significant, but temporary. Several years may be required for the vegetation to stabilize this area to its former condition.

Recreation

Short-term. Recreational opportunities in and around Lake Apopka will be totally forfeited during the restoration project. Even at present, however, little if any recreation occurs on the lake. Boaters are seldom seen and the green waters are unappealing to swimmers (ECFRPC, 1972a). Because of this situation, the drawdown will cause no significant adverse impacts on recreation either in Apopka or the downstream lakes. Sportfishing and boating will still occur throughout the chain of lakes, but potential fish kills could detract from the pleasure of such activities. These combined effects will be temporary and are not expected to result in any serious losses of recreation.

Long-term. The most significant benefit of the Lake Apopka restoration project, resulting from improved water quality, will be an increase in sportfishing and other recreational opportunities. Recreation demand is constantly increasing in the Oklawaha Basin as population growth, leisure time, income, and mobility increase (ECFRPC, 1971). The availability of Lake Apopka as a water-based recreation site will greatly aid in meeting this demand.

Numerous recreational opportunities will exist when the lake's water quality improves and water-based activities such as swimming, wading, and water skiing are possible again (Dawkins and Assoc., Inc., 1975). Non-water contact sports including boating and fishing will also increase. In addition, Magnolia Park and other lakeside parks will offer more recreational opportunities and should experience a corresponding increase in use (Blanchard, Orange Co. Parks Dept., personal communication). In short, both active and passive recreational activities will be enhanced upon completion of a successful restoration.

Recreational benefits will also accrue in downstream lakes as improved Lake Apopka water flows throughout the chain. Fishing and boating should increase and body contact water sports will benefit from the improved water quality (ECFRPC, 1972a). Aside from these primary recreational benefits, the area should receive an economic boost as recreational demand for Lake Apopka increases and supportive facilities develop. A successful drawdown will extend the productive recreational and aesthetic life span of Lake Apopka; the lake will continue to age, but at a much slower rate (Florida DPC, 1972).

Restoration of Apopka will subsequently decrease recreational pressures on nearby lakes which have absorbed the demand formerly associated with Lake Apopka. This change will enhance the natural value of these lakes by decreasing human pressures on the lake ecosystems. Local economies will reflect this change negatively, however, as financial inputs associated with recreation at these lakes are redirected to the Lake Apopka vicinity.

Although the recreational benefits of a restored Lake Apopka are desirable, increased use of the lake will cause some long-term adverse impacts. Heavy recreational use of a lake often results in congestion and crowding of lakeside parks, boat ramps, docks, and highways, with resultant noise and visual pollution. Litter, oil and gas spills, and shoreline erosion from boat wakes are also common. The physical size of Lake Apopka will mitigate congestion and activity conflicts on the lake, but some crowding may still occur on the lake shore. These effects, however, are insignificant compared to the benefits of a restored lake and are normal impacts of any water-based recreation site.

Economy

Drawdown-induced effects on land use and recreation will be reflected in the area's economy. A benefit-cost analysis of this relationship was conducted to provide an economic perspective of the restoration project. This analysis can be used as an important decision-making criterion and is contained in Appendix C.

Short-term. During the drawdown project, fish camp operators and commercial fishermen on Lake Apopka may lose any income they presently derive from the lake. These losses will be minimal for the fish camp owners because few tourists fish the lake and business is virtually nonexistant.

Commercial fishermen do harvest catfish from Lake Apopka, but seldom depend on one lake for their livelihood. Actually, these commercial fishermen could realize a net financial gain from a drawn down Lake Apopka if they were permitted to fish the lake for both catfish and shad prior to and during the drawdown. A local market for catfish already exists and the large standing crop of shad could be sold as crab bait. Fish will be concentrated in the remaining deep pools of water and could be caught easily if gill or haul seine nets were permitted, thereby removing nutrients from the lake. This process would increase the probability of successful water quality improvement, although the extent of such a benefit is relatively unknown.

Heavy materials such as concrete and rocks will be purchased from local suppliers, thereby increasing their business during the drawdown. Additional benefits may accrue to local landowners who sell or lease easements in conjunction with the restoration project.

Long-term. The benefits of a restored Lake Apopka will be most heavily reflected in the income generated by tourists and residents who utilize the lake as a recreational resource. Gas stations, restaurants, fish camps, grocery stores, and other businesses will benefit from these recreationists and fishermen. Also, the restoration of a water-based recreation site in such close proximity to Orlando should guarantee a steady demand for Lake Apopka's facilities. The lake may also attract a percentage of the millions of visitors who travel to Disney World each year via U.S. 27. The heavy recreational use of Apopka in the 1940's occurred long before the creation of Disney World and the tremendous growth of Orlando. These developments can only add to the lake's demand.

Construction of recreational facilities to meet increased demand will further expand the local economy and generate additional revenue. A cycle of demand, supply, and increased cash flow could result from this restoration project. The input of tourist and other outside money will strengthen and diversify the local economy, although the extent of this input will be determined by the success of the drawdown itself.

Commercial harvesting of catfish on Lake Apopka should also benefit from the restoration project. Catfish populations in Lake Carlton have increased since that lake was drawn down and commercial harvesting on Carlton has increased accordingly (Johnson, FG&FWFC, personal communication). The current standing crop of catfish in Lake Apopka, as estimated by 1976 FG&FWFC samples, is approximately 53,139 kg (117,172 lbs) or 4.25 kg/ha (3.78 lbs/acre). Assuming a monthly optimum sustainable yield of 20 percent, commercial harvesting on the lake could yield 127,500 kg (281,138 lbs) annually (4.25 kg/ha X 12,500 ha X .20/month X 12 months = 127,500 kg). Post-drawdown annual yields are expected to exceed this amount as catfish populations increase.

Besides the income generated by the recreational aspects and development of the lake, land values are expected to increase for properties adjacent to the lake. Not only will improved water quality raise values, but demand for the limited remaining developable lakeside sites may cause values to rise even further. The close proximity to Orlando further increases the marketability of these parcels. Downstream property values may eventually increase as water quality in these lakes improves through the continual flushing effect of Apopka. All of these factors will result in increased revenues for the local governments. Sales, taxes, and service-oriented businesses will increase in relation to the demand for such opportunities and will be reflected in a stronger economy.

These economic impacts are discussed in detail in the benefit-cost analysis contained in Appendix C.

Meteorological Impacts and Mitigative Steps

A lake can significantly moderate downwind temperatures, thus influencing agriculture in the vicinity of the lake. Bartholic and Bill (1977) gave two pertinent examples, one the presence of fruit orchards on the eastern shore of Lake Michigan and the other the presence of citrus groves south of some Florida lakes. In both cases, crops are produced on land that would otherwise not be climatically suitable.

When drawdown began to emerge as a likely restoration technique for Lake Apopka, representatives of the citrus industry in the area expressed concern over the possible loss of frost/freeze protection during the drawdown. DER responded to this concern in 1977 by commissioning J.F. Bartholic and R.G. Bill, Jr. of the University of Florida's Institute of Food and Agricultural Sciences to conduct a study of the frost/freeze aspects of a drawdown of Lake Apopka. Their final report is included in Appendix D, and a brief summary is presented below.

Bartholic and Bill used the following methods to evaluate the frost/freeze protection resulting from Lake Apopka:

1. Historical temperature records.
2. Federal Crop Insurance premiums.
3. Remote sensing with satellites and aircraft.
4. Mathematical models.

All four methods indicated that Lake Apopka does provide substantial frost/freeze moderation to the south and southeast of the lake. On cold nights, temperatures downwind of Lake Apopka can be up to 4° C (8° F) warmer than in unmoderated areas. Greatest warming occurs at the edge of the lake, and the warming effect decreases rapidly with increasing distance from the lake. However, low temperatures are moderated by Lake Apopka up to 6.5 km (4 mi) downwind.

Bartholic and Bill used a mathematical model to further investigate the frost/freeze aspects of a drawdown. They learned that a complete drawdown during the winter would seriously jeopardize citrus groves south and southeast of Lake Apopka. During freezes, mucklands, due to their soil characteristics, tend to have very cold temperatures. During the drawdown, the exposed bottom would be equivalent to muckland, and temperatures at the southern edge of the lake would be significantly lower than in areas unaffected by the lake. This lowering of temperatures would extend 5 km (3.1 mi) from the present edge of the lake.

On the other hand, Bartholic and Bill learned that a limited drawdown of Lake Apopka would probably not seriously affect citrus groves. Their model predicts that if the lake were lowered to 19.5 m msl (64 ft msl), a drawdown of approximately 0.6 m (2 ft), the air temperature on cold nights at the southern edge of the lake would be lowered by only 0.5° C (1° F) relative to a full lake. At 19.5 m msl the area of the lake would be essentially unchanged.

A thorough consideration of Bartholic and Bill's findings resulted in severe time constraints being placed on the proposed drawdown. The lake level must be maintained at 19.5 m (64 ft) during December, January, and February, the months of frost/freeze danger.

Representatives of the citrus industry in the Lake Apopka area reviewed Bartholic and Bill's findings and requested that further studies of the frost/freeze problem be done. DER and EPA staff carefully considered this request and concluded that further investigations would not likely produce additional benefits.

The proposed drawdown to 17.7 m (58 ft) msl, with its subsequent muck consolidation, is expected to increase the volume of Lake Apopka by 13 percent. Upon refill, this increase in volume will provide additional frost/freeze protection for citrus orchards downwind of Lake Apopka.

Impacts of Increased Lake Beauclair Sedimentation and Subsequent Drawdown

The use of an in-lake rather than an on-land sedimentation basin during the Lake Apopka drawdown is likely to cause increased sedimentation within Lake Beauclair. Correction of damage to Lake Beauclair will be accomplished via a drawdown subsequent to the refill of Lake Apopka. As in the case of the Apopka drawdown, restoration of Lake Beauclair will also create certain impacts for which mitigative steps may be required.

Water Quality

Possible water quality changes in the Oklawaha Chain of Lakes, attributable to the Apopka drawdown, have already been discussed (section entitled: Water Quality Impacts and Mitigative Steps). In spite of all the mitigative steps planned, there is a high probability that suspended solids will be transported downstream to Lake Beauclair during drawdown. Engineers of RSB&W have determined that virtually all suspended solids exceeding state standards will settle in Lake Beauclair, and will not be carried any further downstream. To correct the effects of this sedimentation, Lake Beauclair will undergo a drawdown shortly after the refill of Apopka. During this drawdown, water will be pumped from Lake Beauclair upstream to Lake Apopka. This water will be identical in nutrient concentration, turbidity and BOD to that water which will have been used to refill Lake Apopka (i.e., water stored during holddown and diluted by Lake Harris water during a reversal of flow in the chain of lakes). The pumpdown of Lake Beauclair will take only 15 days because of the lake's small volume. Due to the short pumping time required and the relatively great length of time available, operators will be able to shut down the pumps whenever winds cause resuspension of bottom sediments in Lake Beauclair. In addition to the factors just noted, the vast difference in water volume between Lakes Apopka and Beauclair (approximately 240:1) would preclude the Lake Beauclair drawdown waters from having a significant effect on the water quality of the refilled Lake Apopka.

Refill of Lake Beauclair will take place by controlled outflow from Lake Apopka via the Apopka-Beauclair Canal. Thus, the water to be used for refill is that which would normally flow to Lake Beauclair.

Biological

I. Flora. The impacts of the Beauclair drawdown upon plant life in and around the lake are virtually identical to those impacts of the Apopka drawdown. All rooted macrophytes in Lake Beauclair will die during drawdown. However, of all the lakes in the Oklawaha chain, Lake Beauclair has the lowest concentration of macrophytes, even less than Apopka (Henley & Chesnut, 1971). Consolidation of Lake Beauclair's sediment through drawdown, combined with clearer water from the Apopka drawdown, will provide an environment that will permit an increased growth of rooted macrophytes in Lake Beauclair after the two restorations.

Maintaining of water levels in nearby bodies of water (Lakes Dora, Carlton and Ola) will prevent a drastic reduction in the water table during the Lake Beauclair drawdown, thereby minimizing impacts on terrestrial plants. If necessary, these lakes can also provide water for irrigation of the citrus groves surrounding Lake Beauclair.

Problems associated with terrestrial weed growth on Lake Beauclair's exposed bottom will be the same as indicated for the Apopka drawdown. Impacts of phytoplankton and bacteria will be similar to those of the Apopka drawdown. However, during the second drawdown, Lake Beauclair water with its related phytoplankton and bacteria levels, will be pumped upstream to Lake Apopka rather than downstream. This may cause some degree of degradation to the newly restored Lake Apopka.

2. Fauna. As with the Apopka drawdown, fish kills in Lake Beauclair should occur when the fish are concentrated in deep holes by the receding water. The high concentration of fish should attract many bird species to the area, including two threatened species (bald eagle and osprey) and one endangered species (wood stork). The fish killed during the Beauclair restoration will be replaced by immigration and succeeding generations of survivors. A restored Lake Beauclair will benefit from an improved gamefishery as described for the Lake Apopka restoration.

The Beauclair restoration will be completed before the alligators' reproductive season; however, receding water during drawdown may initiate an emigration to surrounding lakes. The population of the Lake Eustis pupfish living in Lake Beauclair may be reduced or eliminated during this second restoration; however, recruitment from Lakes Dora and Carlton will rebuild the population of this threatened species after restoration is completed. With even less vegetation than Apopka, Lake Beauclair is currently unable to support a sizeable population of round-tailed muskrats (a species of special concern). Successful restoration of Lake Beauclair will provide a new territory for muskrat populations.

3. Human Health Hazards. Unlike Apopka, Lake Beauclair has never received virus-containing sewage effluent. Therefore, the bottom sediments of Lake Beauclair should be relatively free of virus. Sedimentation of virus-containing solids in Lake Beauclair during the Apopka drawdown may increase the virus concentration in Lake Beauclair. However, "the level of virus surviving in the sediments should be extremely low," (Wellings, ERC, personal communication).

Presently, Lake Beauclair is relatively free of Naegleria, the agent causing primary amoebic meningoencephalitis in man (Wellings, ERC, personal communication). Personnel from ERC plan to use Lake Beauclair as a control lake in an EPA funded study to determine why some lakes support Naegleria and others do not. The drawdown of Apopka, with sedimentation in Beauclair, is likely to introduce Naegleria to Lake Beauclair. This may interfere with ERC's use of Lake Beauclair as a control in addition to increasing the health hazards to swimmers in the lake. The subsequent drawdown of Lake Beauclair may cause a concentration and population explosion of Naegleria in Beauclair as was described for the Apopka drawdown.

Impacts of the bacteria Aeromonas and of mosquitos will be similar to those mentioned for the Apopka drawdown. No reasonable mitigative steps exist for the control of Aeromonas; mosquito control, as described for Lake Apopka, may be required during the Beauclair drawdown.

Physical and Socioeconomic

Lake Beauclair should experience the same basic impacts as those discussed for the Lake Apopka drawdown, but on a reduced scale. The lake will increase in volume slightly as the muck deposits consolidate and slight changes in the lake bottom will result from a dredged pump sump and channel. Deposition of dredged spoils and construction of the pumping station at the mouth of the Apopka-Beauclair Canal are potential sources of soil erosion. As in the Apopka drawdown, however, efforts will be made to contain exposed soils and prevent such inputs to the adjacent lake (RSB&W, personal communication). Similar care will be practiced in the construction and removal of the coffer dams that will separate Lake Beauclair from Lakes Carlton and Dora.

Compared to Apopka, odor problems should be insignificant during the Beauclair drawdown because there will be less total biomass to decompose. Also, removal of fish by commercial fishermen may be aided by the close proximity of Trimble Park on the southern shore of the lake. The boat ramp at this park will give fishermen immediate access to the lake; therefore, they will probably follow the same procedures that allowed them to fish Lake Carlton during its drawdown. If fish are removed there is less chance of an odor problem during the drawdown.

Noise and air quality impacts will be similar to those experienced during the Apopka drawdown. Again, since the Beauclair drawdown is much smaller, these impacts will be correspondingly reduced.

The water table will lower around Lake Beauclair as the lake is drawn down, but lateral movement of groundwater from adjacent lakes will minimize this impact. In addition, irrigation water for affected citrus orchards will be provided as in the Apopka drawdown. No frost/freeze damage to citrus crops is expected as the Beauclair drawdown will not begin until March 1. Also, drawdown-related flooding of adjacent lands is improbable because no water will be stored in downstream lakes.

Until the drawdown and holddown of Lake Beauclair are completed, however, the Apopka-Beauclair Canal (the only outfall of Lake Apopka) will be blocked off. As a result, flooding of areas around Lake Apopka is a potential concern. To estimate how much water Lake Apopka might receive until the end of the Beauclair holddown, refill to 19.5 m (64 ft) msl was assumed to be complete by October 31 and maximum design rainfall was assumed during that winter and the Lake Beauclair restoration. A monthly water balance for Lake Apopka was calculated by RSB&W, thereby allowing estimates of the resulting lake stage.

Based on these assumptions and calculations, RSB&W calculated that the maximum regulatory level of Lake Apopka (20.6 m) will not be exceeded until May 14. Therefore, there will be at least 75 days (March 1 to May 14) to draw down, hold down and begin refill of Lake Beauclair before any potential flood problems will exist around Lake Apopka.

Because most of the land surrounding Lake Beauclair is not suitable for residential development, little if any long-term urban encroachment on citrus lands is expected. Also, developable land on the eastern shore of the lake is already lined with large lot residential dwellings. The majority of the remaining shoreline lies within the flood-prone area and is expected to remain as productive agricultural land, regardless of the lake's water quality.

Recreational use of Lake Beauclair will definitely be forfeited during the restoration project. Trimble Park, which currently experiences moderate to heavy use, will be the most severely impacted public recreation site. Recreational use of the lake originating from lakeside landowners will also temporarily cease, as the exposed lake bottom will not permit any of the normal water related recreational activities. These effects are temporary and will be rectified once the lake is refilled. To prevent possible human health hazards, the Trimble Park site should be posted and closed off during the restoration project.

Following completion of the Lake Beauclair restoration, recreation on and around the lake should be greatly enhanced. Trimble Park's recreational potential will definitely be increased as water quality and fishing improve and as water contact sports become possible. Depending upon the success of the restoration project, Trimble Park may eventually experience overcrowding and the negative impacts associated with such heavy use. When combined with Magnolia Park on Lake Apopka, however, the Orange County Parks Department will once again offer two high quality water-based recreational sites.

Commercial development of fish camps or recreation-oriented businesses on Lake Beauclair may not be feasible because of the lake's small size and its relation to other lakes. Beneficial economic effects will be realized, however, as recreational expenditures increase and lakeside property values are enhanced. Further benefits may accrue to commercial fishermen should the lake support enough catfish to make commercial harvesting profitable. The other intangible benefits associated with the Apopka drawdown will also apply to the Beauclair project. Although no value can be placed on improved water quality, aesthetic appearance, or improved lake ecosystems, these benefits will be experienced by all who come into contact with a restored Lake Beauclair.

SECTION 6

PUBLIC PARTICIPATION PROGRAM

During the drafting of the Lake Apopka Environmental Impact Statement, both EPA and DER wanted to make special provisions for ascertaining and responding to public concerns. On March 7, 1978, a public meeting was held in Eustis, Florida, to discuss the outline of the EIS and to solicit public comments on the restoration of Lake Apopka. More than 100 people attended this meeting and the majority of those who spoke were in favor of an immediate restoration of Lake Apopka.

To assist in the preparation of the EIS document, a Citizens' Review Committee was formed. The people who were asked to serve on the Citizens' Review Committee represented citrus growers, muck farmers, sport fishermen, commercial fishermen, fish camp owners, area college students, mobile home park owners, downstream property owners, environmental groups, and local pollution control agencies. The Committee members were to serve as the Department's link with the public, to help DER define the significant issues in regard to Lake Apopka and to provide an early review of the EIS task reports. Table 6.1 lists the members and alternate members of the Citizens' Review Committee.

The Committee held four meetings during the preparation of the EIS, alternating between afternoon and evening sessions. Following an early suggestion of one member, the meetings were also held in a different community each time. The schedule was as follows:

April 18	7 p.m.	Orlando
May 25	3 p.m.	Winter Garden
June 26	7 p.m.	Apopka
September 18	2 p.m.	Tavares

At each meeting, members of the public attended and participated in the discussions even though not officially part of the Committee.

Two other committees which had been formed by the Department long before the EIS procedure began, the Technical Advisory Committee and the

Table 6.1. Members of Citizens' Review Committee and Alternates.

Member	Alternate
W. Rex Clonts Oviedo	W. R. Clonts, Jr. Apopka
Joe E. Hill Leesburg	Ted Wicks Tavares
Ray Miller Orlando	Winston Borkowski Altamonte Springs
C.E. Heppberger Leesburg	George Keiser Leesburg
W.S. Hodgkiss Tavares	John F. Dequine Leesburg
Maria E. Viamonte Orlando	Stefani Scott Orlando
Walter H. Kuhrt, Jr. Orlando	none
Ed Highsmith Orlando	Charles R. McClellan, Jr. Longwood
C.A. Root Winter Garden	William Arrington Oakland
Ervin Wetzel Apopka	Annie D. Gilliam Apopka
Dan McKinnon Winter Garden	Maurice Boyd Winter Garden
Marci Arthur Tangerine	Russell F. Fisher Winter Park
R.W. Sherman Killarney	D.C. Steorts Montverde
Ben Sibley Maitland	John M. Bateman Orlando
James W. Hayes Winter Garden	Tom Raymond Winter Garden
John A. Carlin Montverde	none
Leon W. Miller Oviedo	Walter Duda Oviedo
Archie Carr, III Maitland	Charles Lee Maitland
Vince Fernandez Apopka	Mrs. Vince Fernandez Apopka
Carlee Metts Winter Garden	Carlton Metts Winter Garden
J. Ken McDuffee Mt. Dora	Fred Wise Mt. Dora

Citrus Advisory Committee, continued their involvement during the drafting of the EIS. Many of the members of the Technical Advisory Committee, experts in such scientific fields as fisheries biology, groundwater hydrology, water management, pollution abatement, or methods of construction, were asked to review draft EIS sections. Their comments offered a different perspective than those of the Citizens' Review Committee and proved helpful to the technical accuracy of the document. A joint meeting of these two committees took place on the morning of May 25, 1978, in Winter Garden.

Speeches were given throughout the Apopka area and at various state conferences to inform citizen groups of the status of the restoration proposal and the EIS. Presentations were made before the following groups:

1.	Lake Improvement Association (This meeting was announced in the Leesburg Area Chamber of Commerce Action Report and in a local newspaper. The Leesburg *Commercial* also carried an article after the speech was presented.)	Leesburg	June 1
2.	Winter Garden Lions Club	Winter Garden	June 12
3.	West Orange Kiwanis Club	Winter Garden	June 13
4.	Winter Garden Rotary Club	Winter Garden	June 13
5.	Apopka Chamber of Commerce	Apopka	June 14
6.	East Central Branch, Florida Section, American Society of Civil Engineers	Deland	August 8
7.	EPA National Conference on Lake Restoration	Minneapolis, Minn.	August 23
8.	Department of Natural Resources' Annual Aquatic Plant Research Review Conference	Tampa	August 30
9.	Central Florida Chapter, Florida Engineering Society	Orlando	September 19
10.	Annual Meeting of the American Society of Civil Engineers, Florida Section	Cypress Gardens	September 22

11.	Natural Resources Committee, Orlando Area Chamber of Commerce	Orlando	September 25
	(A follow-up article was printed in the Orlando Sentinel on September 26, 1978.)		
12.	Department of Environmental Engineering Sciences, Fall Seminar Series, U of F	Gainesville	October 27
13.	South Lake County Rotary Club	Clermont	November 30
14.	Clermont Lions Club	Clermont	November 30

Brochures explaining the degraded condition of Lake Apopka, major causes of this condition, anticipated benefits, and possible temporary side effects of restoration were distributed at these meetings. They were also made available through the following offices:

1. St. Johns River Water Management District, Palatka
2. Winter Garden Chamber of Commerce, Winter Garden
3. Florida Audubon Society, Maitland
4. Department of Environmental Regulation, district office, Orlando

There were several other opportunities for citizens to exchange ideas with government employees regarding this project. At both the March 15, 1978, meeting of the Governing Board of the SJRWMD and the June 28, 1978, meeting of the Oklawaha River Basin Board, the project status was discussed by DER and SJRWMD staff. Board members as well as those in the audience were given the opportunity to ask questions. Briefings of this sort will continue as the two agencies work together toward obtaining the necessary permits for the project.

Displays of posters, slides, and handout materials on Lake Apopka were exhibited at the following conferences or fairs:

1.	Florida State Fair, Tampa	March 29-April 9
2.	Clean Water Conference, Tallahassee	April 6
3.	National Conference on Lake Restoration, Minneapolis, Minn.	August 22-24

DER personnel estimated that 2100 visitors stopped at the agency's booth during the twelve days of the Florida State Fair.

A feature article on the Lake Apopka restoration was published in the June/July 1978 issue of the Environmental Regulation News, a DER publication which has a mailing list of 2500 people. In October, 1978, a full-length article on Lake Apopka with photographs was highlighted in the magazine of the Florida Audubon Society, The Naturalist. Another article appeared in the August/September edition of the United Bass Fishermen's publication, Outdoors. A follow-up story with further details about project construction, presented in an interview-type format, was published in the December/January edition of this same magazine.

Mention of the Apopka restoration effort was also made in the EPA Journal dated May, 1978, and in the April, 1978, edition of the Camp, Dresser, and McKee Newsletter. Camp, Dresser, and McKee is the parent company of Ross, Saarinen, Bolton and Wilder, Inc., consulting engineers on this project.

A large public workshop/meeting was held on November 2, 1978, in Tavares. All those who attended the March "scoping" meeting were invited, as well as any others who had subsequently contacted the Department regarding the Lake Apopka project. At this meeting, the selected anticipated alternative was presented to the group. Schematic slides were shown, depicting the structures to be built, and numerous questions were answered by the engineers of Ross, Saarinen, Bolton and Wilder.

An abstract has also been submitted by RSB&W to the American Society of Civil Engineers (A.S.C.E.). If this abstract is accepted, their speech will be given before the A.S.C.E. National Convention in October, 1979.

SECTION 7
GLOSSARY

AEROBIC

Living, active, or occurring only in the presence of oxygen.

ALGAL ASSAY

A test to determine the limiting factor for the algae of a body of water. In the laboratory, various nutrients are added to lake water containing algae to determine the nutrient promoting further growth and reproduction. That nutrient is the limiting factor for the algae in that lake.

ALGAL BLOOM

An explosive growth of microscopic algae living in the water column of a body of water; can produce discoloration, odor, and occasional toxicity problems.

AMBIENT

Any unconfined portion of the atmosphere; the outside air.

AMMONIA (NH_3)

A chemical compound produced by bacterial breakdown of organic nitrogen material and by excretion of urea and amino acids by aquatic organisms. More than 0.1 mg/l of ammonia in water usually indicates organic pollution.

AQUICLUDE

A formation, or group of formations which yields inappreciable quantities of water to drains, wells, springs, and seeps, and through which there is inappreciable movement of water.

AQUIFER

A saturated bed, formation, or group of formations which yields water in sufficient quantity to be of consequence as a source of supply.

ARTESIAN AQUIFER

A type of aquifer in which groundwater is confined under pressure by overlying and underlying impermeable formations and in which water levels in wells rise above the top of the aquifer.

BENTHOS

Organisms living on or in the bottom of a body of water; benthos is most commonly used for bottom-dwelling invertebrates.

BIOCHEMICAL OXYGEN DEMAND (BOD)

The amount of oxygen required by the organisms in a water sample to oxidize the organic matter in that water. It is usually determined over a five-day period under standardized laboratory conditions, and thus is called BOD_5.

CARBON MONOXIDE (CO)

A colorless, odorless, highly toxic gas that is a normal product of incomplete fossil fuel combustion. CO is one of the most widely distributed and most commonly occurring air pollutants.

CLASS II AIR

Ambient air of better quality than the maximum standards set by EPA.

CULTURAL EUTROPHICATION

Overenrichment of a body of water with nutrients resulting from man's activities.

DENDRITIC

A branching drainage pattern which resembles a tree. (Greek: dendron, tree)

DISSOLVED OXYGEN (DO)

The concentration of oxygen dissolved in water; it is an indication of the balance between oxygen-consuming and oxygen-producing processes at the moment of sampling. DO concentrations should be greater than 5 mg/l for maintenance of diversified biological populations.

ECOSYSTEM

Groups of organisms and their physical environments interacting with one another. These interactions generally concern the procurement of energy or food material.

EUTROPHIC

Rich in dissolved nutrients and seasonally supporting dense populations of microscopic algae and/or larger plants.

FOOD WEB

All of the pathways of energy-flow through the living components of an ecosystem.

GROUNDWATER

The supply of freshwater under the earth's surface in soil or an aquifer that partly or wholly fills the accessible cracks and pore spaces between soil particles, mineral grains, and rock fragments.

HYDROCARBONS

Incomplete fuel combustion and evaporation of gasoline from motor vehicles and storage tanks produce hydrocarbons. Hydrocarbons also play a role in the formation of smog.

INORGANIC NITROGEN

Nitrite, nitrate, and ammonia are forms of nitrogen. Because nitrogen is one of the nutrients essential for accelerated eutrophication of water bodies, its concentration in water is one of the measures of the trophic state of lakes.

INVERTEBRATE

An animal lacking a backbone.

KARST

A limestone region characterized by sinkholes, underground streams, caverns, and subterranean drainage.

LIMITING FACTOR

One of a set of substances present in the proportionally least amount, but necessary for the growth and reproduction of a given organism. The lack of this substance prohibits the use of other substances, while further growth and reproduction of the organism is prevented.

LITTORAL ZONE

The shoreline area of a body of water; as used here, the zone extending from the water's edge to the lakeward limit of rooted aquatic vegetation.

MACROPHYTE

Literally translated as "big plant," this term is generally reserved for plants easily seen with the naked eye.

MICROBE

Any microscopic organism.

NITRATE

The most highly oxidized phase in the nitrogen cycle; it normally reaches important concentrations in the final stages of biological oxidation, and is the form of nitrogen most readily used by green plants.

NITRITE

An intermediate stage in the nitrogen cycle; it may occur in water as a result of the biological decomposition of proteinaceous materials. When correlated with the concentration of other nitrogen forms, trace amounts of nitrite may indicate organic pollution.

NITROGEN DIOXIDE (NO_2)

Nitrogen dioxide is emitted by automobiles and furnace stacks. It is also produced during certain chemical processes and through the burning of fossil fuels. NO_2 is corrosive, highly oxidizing and physically irritating to those susceptible to respiratory infections.

NON-ARTESIAN AQUIFER

A type of aquifer in which groundwater possesses a free soil surface open to the atmosphere; gravity is the only pressure affecting water flow in this type of aquifer.

NUTRIENT

A substance essential to growth and reproduction in living systems; carbon, nitrogen and phosphorus are the most critical nutrients in aquatic systems.

ORGANIC NITROGEN

Decomposed nitrogen-containing compounds, originally produced in living systems. A rise in the organic nitrogen content of a body of water may often be related to sewage or industrial waste pollution.

OXIDATION

A chemical reaction in which oxygen unites or combines with other elements. Organic matter is oxidized by the action of aerobic bacteria.

OZONE

A pungent colorless, toxic gas. Ozone is one component of photochemical smog and is considered a major air pollutant.

PARTICULATES

Small solid particles which remain suspended in air until their weight, a rainstorm, or some other factor settles them out. Industries, transportation, heating sources, pollen, and natural dust all contribute to concentrations of particulates.

PERMEABILITY

A measure of the ease of movement of groundwater through soils and rock formations.

pH

A measure of the degree of acidity (pH is less than 7) or alkalinity (pH is greater than 7). The pH of natural waters varies over a wide range, but the pH values of most fresh waters in Florida range from 4 to 9, with eutrophic lakes sometimes reaching 12.

PHOSPHORUS

One of the most important plant nutrients. Because it is one of the least abundant of available nutrients in U.S. waters, high values of phosphorus are usually indications of cultural enrichment.

PHYSIOGRAPHIC

A type of configuration of a surface area including relief, or relative elevations, and the position of natural and man-made features.

PHYTOPLANKTON

Microscopic, single-celled plants that float passively or swim weakly in a body of water. The phytoplankton belong to a group commonly called algae. However, some algae are quite large and therefore considered macrophytes.

POROSITY

A measure of the interstitial space of a rock (the space between soil and mineral particles). Porosity is expressed quantitatively as the percentage of the total volume of rock occupied by interstitial spaces.

POTABLE

Suitable for drinking or cooking purposes from both health and aesthetic considerations.

POTENTIOMETRIC SURFACE

A surface which represents the fluid potential of water in an aquifer. It is the level to which water will rise in tightly cased wells penetrating the aquifer.

RELIEF

The difference in elevation between the highest and lowest points in a specified area.

SOIL ASSOCIATIONS

A landscape that has a distinctive proportional pattern of soils. It normally consists of one or more major soils, and it is named for the major soils. The soils in one association may occur in another, but in a different pattern.

STORET

A computerized and centralized data base established by the EPA which contains water quality information from numerous federal, state, regional and local agencies.

SULFUR DIOXIDE (SO_2)

Nonflammable, nonexplosive, colorless gas which is the result of fossil fuel combustion (coal, oil, gas) for the generation of electrical power.

SUPERSATURATED

As used in this document, a condition in which the concentration of oxygen dissolved in water is higher than would normally be found under given conditions of temperature and pressure. This condition is generally due to high photosynthetic activity of phytoplankton and aquatic macrophytes.

TURBIDITY

A measure of the amount of light transmitted through water; increased turbidity is primarily due to small suspended particles.

VERTEBRATE

An animal with a backbone.

WATERSHED

The region or area drained by, or contributing to, a stream, lake, or other particular watercourse or body of water.

WATER TABLE

The upper surface of groundwater. Below the water table every space between soil and mineral particles is saturated with water. Above the water table, these interstitial spaces are only partly filled with water.

ZOOPLANKTON

Passively floating or weakly swimming animals, usually microscopic, inhabiting a body of water.

SECTION 8
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APPENDIX A

WATER QUALITY DATA

WATER QUALITY MONITORING STATIONS

LOCATION	LOCATION NO.	STATION NO.
Oklawaha River	1	20020383
	2	20020306 (121401)
Lake Griffin	1	20020379
	2	02238300
	3	121401
	4	20020380
	5	121402
	6	20020381
	7	121403
	8	20020382
Lake Harris	1	02237520
	2	20020375
	3	20020377
	4	20020376
Little Lake Harris	5	20020374
	6	20020373
Lake Yale	1	124601
	2	20020372
	3	124602
	4	20020371
	5	02238200
Lake Eustis	1	02237900
	2	20020369
	3	20020368
	4	20020367
Trout Lake	1	124201
Lake Dora	1	20020365
	2	120801
	3	20020364
	4	120802
	5	20020363 & 120803
	6	02237800
Lake Beauclair	1	20020362
Lake Carlton	2	20020361

WATER QUALITY MONITORING STATIONS

LOCATION	LOCATION NO.	STATION NO.
Lake Apopka	1	120201
	2	120204
	3	120202
	4	120203
	5	120206
	6	02237600
	7	120205

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SUMMARY OF WATER QUALITY DATA

LAKE APOPKA

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD₅ mg/l	00605 Org N mg/l	00610 NH₃-N mg/l	00630 Inorg N mg/l	00625 Kjel N mg/l	00671 DiaOrthoP mg/l	00665 Tot P mg/l	Depth ft	32217 Chl a ug/l
120201	NES	3/12/73	26.1	9.40	10.4			0.160	0.2	3.10	0.016	0.083	0	33.4
		9/ 6/73	28.2	8.70	6.8			0.100	0.1	5.40	0.034	0.169	0	63.2
		11/ 7/73	23.4	9.30	10.2			0.070	0.1	3.30	0.017	0.080	0	22.2
120202	NES	3/12/73	25.5	9.50	10.4			0.160	0.2	3.00	0.014	0.124	0	35.9
		9/ 6/73	28.3	8.80	7.0			0.180	0.1	4.40	0.030	0.140	0	18.4
		11/ 7/73	22.6	9.50	10.2			0.070	0.1	3.50	0.015	0.072	0	27.8
120203	NES	3/12/73	25.5	9.50	10.0			0.180	0.2	3.30	0.016	0.121	0	39.9
		9/ 6/73	29.5	8.70	10.0			0.190	0.3	4.50	0.029	0.117	0	88.4
		11/ 7/73	22.9	9.50	9.6			0.080	0.1	3.80	0.024	0.090	0	23.7
120204	NES	3/12/73	25.5	9.60	10.0			0.140	0.2	3.10	0.012	0.086	0	25.5
		9/ 5/73	28.2	8.80	7.6			0.100	0.1	4.90	0.031	0.093	0	99.1
		11/ 7/73	24.4	9.50				0.070	0.1	3.20	0.017	0.075	0	39.9
		11/ 7/73	22.3	8.90	8.2			0.080	0.1	3.90	0.030	0.115	6	
120205	NES	3/12/73	26.0	9.50	10.3			0.240	0.3	3.50	0.017	0.098	0	30.1
		9/ 5/73	29.6	9.00	10.2			0.160	0.2	5.00	0.031	0.126	0	105.6
		11/ 7/73	23.3	9.40	9.4			0.070	0.1	3.30	0.019	0.088	0	26.8
120206	NES	3/12/73		9.50	11.1			0.160	0.2	3.20	0.014	0.120	0	29.5
		9/ 5/73	29.7	8.80	11.0			0.190	0.3	4.90	0.036	0.319	0	92.7
		11/ 7/73	23.2	9.40	9.2			0.080	0.1	3.90	0.025	0.102	0	28.9

SOURCE: STORET
PREPARED BY: HAYES, SUDDERTH & ETHEREDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE APOPKA

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD$_5$ mg/l	00685 Org N mg/l	00610 NH$_3$-N mg/l	00615 00620 Inorg N mg/l	00650 TotPO$_4$ mg/l	00660 OrthoPO$_4$ mg/l	00665 Tot P mg/l	70507 OrthoP mg/l	71886 Tot P-PO$_4$ mg/l
02237600	USGS	5/8/68	23.0	7.50	10.0				0.28	0.73		0.240		
		4/24/69	26.0	7.00	11.0				6.30	0.79		0.260		
		5/13/70	27.0	8.20	16.1	5.5	2.70	0.062	0.003	0.89	0.73	0.290	0.240	
		9/29/70	24.0	8.20	10.1	6.2	2.70	0.070	0.009	0.57	0.15	0.190	0.049	
		4/28/71	25.0	7.60	7.8		8.20	0.120	0.006		0.17	0.190	0.056	
		9/13/71	28.0	7.50	8.0	8.3	13.00	0.450	0.780		1.20	0.490	0.390	
		4/20/72	26.0	7.00	3.0	8.0	4.30	0.010	0.004			0.048	0.045	
		9/7/72	31.0	8.60	7.3	6.6	4.50	0.240	0.010			0.033	0.012	
		5/23/73	27.0	8.90	11.7	4.4	3.60	0.090	0.070			0.025	0.015	
		11/6/73	24.0	9.20	11.4	5.8	3.50	0.010	0.010			0.086	0.007	
		5/13/74	24.8	8.20	6.24		5.70	0.010	0.010			0.180	0.030	
		7/25/74	30.7	8.80	6.67	6.9	3.80	0.010	0.010			0.100	0.030	
		10/9/74	22.7	8.50	8.36	4.9	3.60	0.010	0.010			0.040	0.020	
		5/7/75	26.8	9.40	10.2	6.8	4.80	0.020	0.020			0.060	0.030	
		8/20/75	30.0	7.30	7.64	2.8	3.50	0.020	0.010			0.050	0.030	
		10/23/75	23.0	9.00	8.8	8.2	2.00	0.040	0.010			0.050	0.020	
		6/3/76	23.8	8.60	11.12	4.9	4.70	0.030	0.020			0.100	0.050	
		7/27/76	29.6	7.20	8.82	6.2	3.80	0.020	0.010			0.110	0.010	
		9/20/76	29.1	9.10	8.86	4.7	2.70	0.010	0.010			0.060	0.060	

SOURCE. STORET
PREPARED BY: MAYES, SUDDERTH & ETHEREDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE BEAUCLAIR

STATION NO. (SOURCE)	DATE	00010 Temp. (°C)	00400 pH	00300 D.O. mg/l	00310 BOD$_5$ mg/l	00605 Org N mg/l	00610 NH$_3$-N mg/l	00615 00620 Inorg N mg/l	00625 Kjel N mg/l	00671 DiuOrthoP mg/l	00665 Tot.P mg/l	70507 OrthoP mg/l	71886 TotP-PO$_4$ mg/l	31501 Tot Col MPN/100ml	31616 Fec Col MPN/100ml
20020362	6/ 8/7	28.0	9.50	10.2	0.6	4.80	0.33	0.323				0.02	0.17		
DER	7/30/7	32.0	8.80	10.3	4.0	2.56	0.12	0.073				0.02	0.08	0	10

SOURCE, STORET
PREPARED BY, HAYES, SUDDERTH & ETHEREDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE DOMA

STATION NO. (SOURCE)	DATE	00010 Temp. (°C)	00400 pH	00300 D.O. mg/l	00310 BOD$_5$ mg/l	00605 Org N mg/l	00610 NH$_3$-N mg/l	00615 00620 Inorg N mg/l	00625 Kjel N mg/l	00671 DisOrthoP mg/l	00665 Tot.P mg/l	70507 OrthoP mg/l	71886 TotP-PO$_4$ mg/l	31501 Tot Col MPN/100ml	31616 Fec Col MPN/100ml
20020363	6/ 5/73	28.0	9.40	8.4	6.0	3.96	0.32	0.112				0.01	0.16		
DER	7/30/74	32.0	8.50	9.8	5.1	2.72	0.10	0.073				0.02	0.09		
20020364	6/ 5/73	28.0	9.40	11.0	5.0	3.24	0.27	0.113				0.02	0.15		
DER	7/30/74	34.0	8.70	10.5	3.9	2.64	0.10	0.083				0.01	0.05	0	0
20020365	6/ 5/73	28.0	9.30	10.9	4.9	3.15	0.30	0.116				0.02	0.16		
DER	7/30/74	33.0	8.70	9.7	4.3	2.84	0.10	0.073				0.01	0.06		

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SUMMARY OF WATER QUALITY DATA

LAKE DORA

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD5 mg/l	00605 Org N mg/l	00610 NH3-N mg/l	00630 Inorg N mg/l	00625 Kjel N mg/l	00671 DisOrthoP mg/l	00665 Tot P mg/l	Depth ft	32217 Chl a ug/l
120801	NES	3/12/73	25.8	9.70				0.100	0.1	2.50	0.011	0.138	0	36.1
		3/12/73	24.6	9.60	10.6			0.140	0.2	2.50	0.014	0.085	6	
		9/ 6/73	29.8	9.10	9.8			0.090	0.1	2.50	0.020	0.065	0	69.0
		11/ 5/73	23.3	9.20				0.090	0.1	3.20	0.030	0.072	0	31.3
		11/ 5/73	23.3		10.4								1	
		11/ 5/73	23.2	9.30	10.6			0.110	0.1	3.20	0.038	0.078	6	
120802	NES	3/12/73	24.0	9.70				0.130	0.16	2.50	0.012	0.093	0	44.8
		3/12/73	23.5	9.70	11.1			0.160	0.20	2.80	0.018	0.100	6	
		9/ 6/73	29.2	9.00	9.2			0.090	0.12	3.90	0.022	0.074	0	71.8
		9/ 6/73	28.3	8.80	7.6			0.120	0.14	4.40	0.034	0.118	6	
		11/ 5/73	22.6	9.30				0.110	0.11	3.90	0.038	0.099	0	63.9
		11/ 5/73	22.6		9.8								1	
		11/ 5/73	22.4	9.30	9.6			0.180	0.17	3.80	0.076	0.108	5	
120803	NES	3/12/73	25.0	9.70				0.100	0.14	2.60	0.011	0.104	0	66.5
		3/12/73	23.6	9.60	10.0			0.140	0.19	3.00	0.016	0.137	6	
		9/ 6/73	29.1	9.10	10.2			0.080	0.10	4.40	0.026	0.115	0	99.8
		9/ 6/73	26.4										5	
		11/ 5/73	23.0	9.40						3.50		0.106	0	56.0
		11/ 5/73	23.0		11.2								1	
		11/ 5/73	23.0	9.40	11.2			0.100	0.13	3.80	0.045	0.117	6	

SOURCE, STORET
PREPARED BY, HAYES, [illegible] & [illegible], INC

SUMMARY OF WATER QUALITY DATA

LAKE DOHA

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD5 mg/l	00605 Org N mg/l	00610 NH3-N mg/l	00615 00620 Inorg N mg/l	00650 TotPO4 mg/l	00660 OrthoPO4 mg/l	00665 Tot P mg/l	70507 OrthoP mg/l	71886 Tot P-PO4 mg/l
02237000	USGS	5/9/70	25.0	8.00	10.0		3.30			0.88	0.67			
		10/6/70	25.0	7.80	1.4	8.0	2.90			1.10	0.48			
		5/11/71	28.0	8.50	2.8	6.6	4.70				0.19			0.45
		9/1/71	29.5	8.20	8.0	6.9	4.80				0.12			0.21
		8/4/72	27.0	9.70	11.7	5.2	4.30	0.010	0.008			0.040	0.020	
		10/5/72	26.0	8.30	8.3	5.4	2.80	0.050	0.010			0.060	0.045	
		5/23/73	29.0	9.20	12.4	6.0	3.10	0.020	0.012			0.035	0.025	
		/30/73	30.0	8.40	8.6	3.5	1.60	0.000	0.006			0.096	0.026	
		11/7/73	23.5	8.80	10.6	6.2	3.10	0.010	0.010			0.072	0.008	
		5/13/74	25.5	9.30	7.1	6.2	4.80	0.020	0.020			0.110	0.030	
		7/28/74	30.8	8.00	7.8	4.4	2.60	0.010	0.010			0.070	0.030	
		10/9/74	22.4		7.3	6.3	3.80	0.010	0.010			0.060	0.030	
		5/7/75	27.0	8.60	7.9	5.9	4.20	0.360	0.070			0.070	0.010	
		/20/75	31.0	7.50	9.3	6.3	3.30	0.020	0.010			0.050	0.040	
		10/23/75	23.5	8.50	7.6	6.3	2.80	0.180	0.010			0.060	0.030	
		5/4/76	24.7	8.80	10.2	8.8	4.40	0.030	0.010					
		7/27/76	30.2	9.00	6.0	5.7	2.80	0.010	0.010					
		9/15/76	25.5	8.30	7.4	2.1	2.90	0.010	0.010					

SOURCE, STORET
PREPARED BY, HAYES, SUDDERTH & ETHEREDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE EUSTIS

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD_5 mg/l	00605 Org N mg/l	00610 NH_3-N mg/l	00615 00620 Inorg N mg/l	00650 $TotPO_4$ mg/l	00660 $OrthoPO_4$ mg/l	00665 Tot P mg/l	70507 OrthoP mg/l	71886 Tot P-PO_4 mg/l
02237900	USGS	3/21/75	20.0		6.0									
		5/21/75	28.0		4.8	4.6								
		9/11/75	28.0		5.2									
		11/7/75	23.6		8.2									
		2/25/76	18.0		8.7									
		4/16/76	21.5		7.6									
		5/4/76	24.0			2.6								
		6/9/76	26.0		7.6									
		8/5/76	29.5											
		10/8/76	26.0		7.1	3.0								
		11/3/76	17.0		7.8									

SOURCE: STORET
PREPARED BY: HAYES, SEDERTH & ETHERIDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE GRIFFIN

STATION NO. (SOURCE)	DATE	00010 Temp. (°C)	00400 pH	00300 D.O. mg/1	00310 BOD5 mg/1	00605 Org N mg/1	00610 NH3-N mg/1	00615 00620 Inorg N mg/1	00625 Kjel N mg/1	00671 DisOrthoP mg/1	00665 Tot.P mg/1	70507 OrthoP mg/1	71886 TotP-PO4 mg/1	31501 Tot Col MPN/100ml	31616 Fec Col MPN/100ml
20020379 DER	6/ 5/73	26.0	8.70	9.0	5.4	2.79	0.32	0.085				0.02	0.17		
	7/30/74	29.0	9.00	8.7	5.0	2.24	0.02	0.053				0.01	0.07		
20020380 DER	6/ 5/73	26.0	9.50	8.6	4.1	2.64	0.27	0.089				0.02	0.17		
	7/30/74	29.0	8.60	8.4	4.1	2.12	0.04	0.063				0.01	0.08		
	11/11/74	21.0	8.70	10.6		3.08	0.16	0.081				0.01	0.14		
20020382 DER	6/ 5/73	27.0	8.10	3.0	5.4	2.61	0.33	0.150				0.03	0.18		
	7/30/74	29.0	8.00	5.8	4.0	2.13	0.02	0.064				0.01	0.08		
20020381 DER	6/ 5/73	27.0	9.10	7.5	5.9	2.91	0.24	0.106				0.020	0.17		
	10/31/73	20.0	8.70	10.2		3.12	0.29	0.124				0.030	0.20	70	0
	12/12/73	11.0	7.80	9.1		2.79	0.10	0.110				0.040	0.17	40	0
	1/ 8/74	23.0	8.40	8.5		1.85	0.06	0.061				0.010	0.11	20	0
	2/ 6/74	17.0	8.50	7.2		1.83	0.200	0.064				0.020	0.14	0	0
	3/ 5/74	20.0	7.80	10.0		1.89	0.120	0.062				0.010	0.11		
	4/ 3/74	24.0	7.70	5.5		2.45	0.060	0.132				0.010	0.18	10	0
	5/ 1/74	25.0	8.50	8.0		2.52	0.180	0.052				0.060	0.22	0	0
	6/ 5/74	29.0	8.80	8.1	5.8	2.10	0.14	0.032				0.000	0.14		
	7/ 9/74	29.0	9.50	8.8	4.2	2.19	0.08	0.063				0.020	0.09		
	7/30/74	29.0	8.50	8.8	4.6	2.28	0.04	0.063				0.010	0.08	30	10
	8/ 6/74	27.0	8.50	6.8	8.4	2.43	0.24	0.062				0.010	0.15	0	
	9/ 3/74	32.0	8.70	10.8	5.8	2.46	0.26	0.052				0.010	0.12	0	0
	10/ 1/74	25.0	8.70	6.0	7.7	2.97	0.18	0.062				0.020	0.13	0	0
	11/ 5/74	25.0	8.70	11.9		2.83	0.00	0.062				0.020	0.10	0	0
	11/11/74	21.0	7.90	8.7		2.43	0.15	0.112				0.010	0.11		

SOURCE, STORET
PREPARED BY, HAYES, SUDDERTH & ETHEREDGE, INC.

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SUMMARY OF WATER QUALITY DATA

LAKE CARLTON

STATION NO. (SOURCE)	DATE	00010 Temp. (°C)	00400 pH	00300 D.O. mg/l	00310 BOD$_5$ mg/l	00605 Org N mg/l	00610 NH$_3$-N mg/l	00615 00620 Inorg N mg/l	00625 Kjel N mg/l	00671 DisOrthoP mg/l	00665 Tot.P mg/l	70507 OrthoP mg/l	71886 TotP-PO$_4$ mg/l	31501 Tot Col MPN/100ml	31616 Fec Col MPN/100ml
20020361 DER	6/ 5/74 7/30/74	28.0 32.0	9.50 8.50	10.1 8.8	6.2 5.8	3.15 3.26	0.27 0.36	0.143 0.074				0.02 0.01	0.16 0.09	 ●	 ●
02237749 USGS	8/ 5/74					3.00	0.360	0.150			0.080	0.050			

SOURCE. STORET
PREPARED BY. HAYES, SUDDERTH & ETHERIDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE GRIFFIN

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD$_5$ mg/l	00605 Org N mg/l	00610 NH$_3$-N mg/l	00630 Inorg N mg/l	00625 Kjel N mg/l	00671 DisOrthoP mg/l	00665 Tot P mg/l	Depth ft	32217 Chl a ug/l
121401	HES	3/14/73	25.5	9.40	9.3			0.170	0.170	3.30	0.013	0.102	0	12.4
		9/ 6/73	29.7	9.00	8.4			0.050	0.110	4.00	0.027	0.122	0	74.8
		11/ 5/73	23.0	9.00				0.120	0.130	3.20	0.047	0.120	0	50.0
		11/ 5/73	23.0		9.6								1	
		11/ 5/73	23.0	8.90	9.0			0.140	0.170	3.00	0.052	0.156	4	
121402	HES	3/14/73	25.5	9.30	9.1			0.100	0.160	2.20	0.012	0.095	0	20.0
		9/ 6/73	29.4	9.00	9.2			0.090	0.100	3.00	0.026	0.095	0	105.9
		11/ 5/73	22.1	8.90				0.120	0.130	3.30	0.055	0.125	0	82.6
		11/ 5/73	22.1		8.8								1	
		11/ 5/73	22.1	8.90	9.2			0.120	0.150	3.40	0.060	0.123	4	
121403	HES	3/14/73	26.2	9.20	9.1			0.100	0.160	2.90	0.012	0.099	0	20.0
		9/ 6/73	29.4	8.90	8.6			0.090	0.110	3.60	0.030	0.083	0	117.8
		11/ 5/73	22.7	8.70				0.110	0.130	3.10	0.047	0.116	0	94.8
		11/ 5/73	22.7		8.8								1	
		11/ 5/73	22.6	8.70	8.8			0.130	0.150	3.00	0.059	0.157	4	

SOURCE: STORET
PREPARED BY: HAYES, SUDDERTH & ETHEREDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE GRIFFIN

STATION NO. (SOURCE)	DATE	00010 Temp. (°C)	00400 pH	00300 D.O. mg/l	00310 BOD$_5$ mg/l	00605 Org N mg/l	00610 NH$_3$-N mg/l	00615 00620 Inorg N mg/l	00625 Kjel N mg/l	00671 DisOrthoP mg/l	00665 Tot.P mg/l	70507 OrthoP mg/l	71886 TotP-PO$_4$ mg/l	31501 Tot Col MPN/100ml	31616 Fec Col MPN/100ml
20020301 DER (CONT'D)	12/ 3/74	12.0	7.80	9.8		2.70	0.090	0.184				0.010	0.13		100
	1/14/75	15.0	8.40	8.7	4.0	2.01	0.100	0.204				0.010	0.27	20	0
	2/ 4/75	23.0	7.90	8.7	6.0	1.86	0.050	0.155				0.010	0.19		
	3/ 4/75	17.0	8.00	10.4	5.2	1.88	0.120	0.163				0.010	0.18	0	0
	4/ 1/75	25.0	8.50	6.6	5.4	2.13	0.120	0.005				0.020	0.10	0	0
	5/ 6/75	27.0	8.40	8.4	6.5	2.21	0.420	0.025				0.020	0.18		
	6/ 3/75	28.0	9.20	7.6	5.6	2.39	0.480	0.056				0.020	0.09	0	0
	7/ 1/75	29.0	8.70	6.2	6.9	2.91	0.200	0.034				0.010	0.06	0	0
	8/ 5/75	29.0	9.00	6.6	5.4	2.47	0.100	0.068				0.040	0.12	10	0
	9/ 2/75	28.0	8.30	6.3	5.2	2.78	0.130	0.037				0.020	0.06		
	9/30/75	26.0	7.50	6.7	9.0	2.91	0.450	0.025				0.070	0.08	10	0
	11/ 4/75	24.0		8.5	6.4	2.80	0.410	0.052				0.030	0.03	40	0
	12/ 2/75	19.0		7.8	4.7	2.56	0.400	0.036				0.020	0.08	20	0
	1/ 7/76	14.0		8.5	6.3	2.01	0.340			0.010	0.090				
	2/ 3/76	14.0	8.00	9.1	1.9	1.86	0.220			0.010	0.010				
	3/ 2/76	21.0	9.00	11.8	7.2	1.80	0.130			0.010	0.170			0	0
	4/ 6/76	24.0	7.80	7.4	8.0	1.98	0.220			0.020	0.070				0
	5/ 4/76	25.0	8.80	10.6	9.0	2.16	0.200			0.010	0.080				
	6/ 1/76	27.0	8.80	8.6	6.4	2.20	0.160			0.020					
	7/ 1/76	26.0	8.70	7.5	4.5	2.07	0.130			0.020	0.030				
	7/ 6/76	20.0	9.10	8.8	8.4	1.88	0.150			0.020	0.020				
	8/ 3/76	29.0	8.80	8.1	8.6	2.91	0.200			0.020	0.050				
	9/ 7/76	31.0	8.70	7.4	3.5	2.29	0.210			0.000	0.170			0	0
	10/12/76			8.1	6.0	2.68	0.260			0.020	0.130				
	11/ 2/76	22.0	8.30	8.7	6.6	2.97	0.230			0.040	0.080				

SOURCE, STORET
PREPARED BY HAYES, SUDDENTH & ETHEREDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE EUSTIS

STATION NO. (SOURCE)	DATE	00010 Temp. (°C)	00400 pH	00300 D.O. mg/1	00310 BOD$_5$ mg/1	00605 Org N mg/1	00610 NH$_3$-N mg/1	00615 00620 Inorg N mg/1	00625 Kjel N mg/1	00671 DisOrthoP mg/1	00665 Tot.P mg/1	70507 OrthoP mg/1	71886 TotP-PO$_4$ mg/1	31501 Tot Col MPN/100ml	31616 Fec Col MPN/100ml
20020368 DER	6/ 5/73	27.0	9.20	8.2	3.4	2.87	0.270	0.094				0.020	0.17		
	10/31/73	21.0	8.80	9.6		3.18	0.330	0.124				0.020	0.19	40	0
	12/12/73	14.0	8.00	9.8		3.48	0.150	0.012				0.020	0.35	30	0
	1/ 8/74	22.0	8.80	12.6		2.43	0.120	0.162				0.010	0.09	40	0
	2/ 6/74	19.0	7.90	8.5		3.22	0.240	0.043				0.010	0.06	10	0
	3/ 5/74	19.0	8.30	11.1		2.58	0.130	0.083				0.010	0.14		
	4/ 3/74	24.0	8.10	7.6		3.32	0.110	0.082				0.010	0.12	10	0
	5/ 1/74	24.0	8.70	7.1		3.43	0.260	0.052				0.010	0.10	0	0
	6/ 5/74	31.0	7.90	6.0	3.7	2.04	0.090	0.045				0.000	0.11		
	7/ 9/74	28.0	9.60	9.4	2.6	1.71	0.090	0.072				0.010	0.06		
	7/30/74	33.0	8.60	9.6	3.5	2.10	0.060	0.063				0.010	0.06	0	0
	8/ 6/74	28.0	8.40	7.3	3.3	2.13	0.170	0.061				0.010	0.09	0	
	9/ 3/74	31.0	8.60	8.4	3.2	2.13	0.230	0.042				0.010	0.07	0	0
	10/ 1/74	26.0	8.40	8.4	4.1	2.52	0.150	0.044				0.020	0.08	10	0
	11/ 5/74	25.0	8.40	9.7		2.37	0.110	0.040				0.010	0.06	0	0
	12/ 3/74	14.0	8.30	8.9		3.24	0.090	0.043				0.010	0.13		640
	1/14/75	16.0	7.80	8.3	6.0	2.90	0.170	0.072				0.010	0.36	50	0
	2/ 4/75	21.0	8.00	8.9	5.1	2.32	0.200	0.146				0.010	0.09		
	3/ 4/75	17.0	8.10	9.9	6.9	2.76	0.100	0.320				0.010	0.14	20	0
	4/ 1/75	24.0	8.60	7.2	8.0	2.80	0.240	0.016				0.010	0.18	0	0
	5/ 6/75	27.0	8.30	5.7	9.2	2.93	0.42	0.023				0.010	0.07		
	6/ 3/75	29.0	8.50	5.2	2.7	1.77	1.08	0.056				0.020	0.05	0	0
	7/ 1/75	30.0	8.70	8.6	3.5	2.33	0.34	0.023				0.020	0.03	0	0
	8/ 5/75	29.0	9.20	8.4	3.1	2.01	0.37	0.067				0.030	0.07	10	0

SOURCE, STORET
PREPARED BY, HAYES, SUDDERTH & LINFREDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE GRIFFIN

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/1	00310 BOD$_5$ mg/1	00605 Org N mg/1	00610 NH$_3$-N mg/1	00615 00620 Inorg N mg/1	00650 TotPO$_4$ mg/1	00660 OrthoPO$_4$ mg/1	00665 Tot P mg/1	70507 OrthoP mg/1	71886 Tot P-PO$_4$ mg/1
02238300	USGS	5/9/70	25.0	7.80	8.4	4.9	0.62			0.19	0.09			
		10/6/70	26.5	7.40	8.9	3.4	0.88			0.26	0.03			
		/10/71	32.0	7.10	9.4	4.5	4.00				0.10			0.21
		9/1/71	29.0	6.90	5.4	5.6	2.60				0.08			0.18
		5/8/72	25.0	8.70	8.3	4.6	3.20	0.000	0.006			0.062	0.020	
		10/6/72	26.0	9.20	9.2	4.0	2.10	0.030	0.016			0.100	0.040	
		/24/73	24.5	7.80	7.8	8.3	2.90	0.000	0.006			0.013	0.010	
		/31/73	28.0	8.00	6.1	7.4L	3.60	0.030	0.000			0.180	0.056	
		11/7/73	22.1	8.10	6.7A	6.6	2.90	0.010	0.010			0.087	0.076	
		/14/74	24.4	8.80	4.8A	8.6	2.60	0.010	0.010			0.140	0.020	
		7/29/74	27.0	7.00	6.4A	3.5	4.70	0.010	0.100		0.440	0.220	0.180	
		10/9/74	22.2	8.80	7.5A	8.9	3.20	0.010	0.010			0.100	0.040	
		5/7/75	27.8	8.90	10.4	7.3	2.60	0.010	0.020			0.030	0.020	
		/20/75	30.5	9.00	9.2	6.8	3.30	0.020	0.010			0.050	0.030	
		10/23/75	23.8	9.10	10.0A	9.1	3.30	0.080	0.010			0.050	0.030	
		5/3/76	26.0	8.70	12.4	4.8	2.40	0.020	0.010			0.050	0.020	
		7/27/76	30.3	7.00	7.7A	4.3	2.20	0.020	0.010			0.070	0.030	
		/15/76	25.3	7.90	7.6A	3.6	2.80	0.010	0.010			0.070	0.040	

A= AVERAGE OF MEASUREMENTS AT SEVERAL DEPTHS
L= LESS THAN

SOURCE, STORET
PREPARED BY, HAYES, SEABERTH & ETHERIDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE EUSTIS

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD$_5$ mg/l	00605 Org N mg/l	00610 NH$_3$-N mg/l	00615 00620 Inorg N mg/l	00630 TotPO$_4$ mg/l	00660 OrthoPO$_4$ mg/l	00665 Tot P mg/l	70507 OrthoP mg/l	71886 Tot P-PO$_4$ mg/l
02237900	USGS	5/18/70	27.0	7.30	11.0		1.90			0.30	0.15			
		5/11/71	27.0		3.2		1.60				0.10			0.29
		12/9/71	20.0		9.3									
		1/17/72	12.5		11.0									
		3/16/72	20.0		9.0									
		5/4/72	26.0	9.40	9.7	4.3								
		6/21/72	25.5		7.0									
		8/10/72	29.5		4.6									
		10/5/72	26.0		8.1	2.7								
		11/17/72	19.5		8.2									
		1/23/73	16.0		6.7									
		3/16/73	24.0		9.9									
		5/17/73	23.0			4.1								
		6/14/73	27.0		7.6									
		8/ 2/73	27.0		6.2									
		9/20/73	28.0		4.5	2.2								
		11/16/73	21.5		7.8									
		1/7/74	20.0		8.5									
		2/28/74	1.70		10.0									
		4/17/74	24.5		8.2	6.5								
		6/14/74	29.5		3.0									
		8/9/74	29.5		3.0									
		9/30/74	28.0		8.1	3.2								
		1/23/75	17.5		8.5									

SOURCE, STORET
PREPARED BY HAYES, SUDDERTH & ETHERIDGE, INC.

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SUMMARY OF WATER QUALITY DATA

LAKE EUSTIS

STATION NO. (SOURCE)	DATE	00010 Temp. (°C)	00400 pH	00300 D.O. mg/l	00310 BOD5 mg/l	00605 Org N mg/l	00610 NH3-N mg/l	00615 00620 Inorg N mg/l	00625 Kjel N mg/l	00671 DisOrthoP mg/l	00665 Tot.P mg/l	70507 OrthoP mg/l	71886 TotP-PO4 mg/l	31501 Tot Col MPN/100ml	31616 Fec Col MPN/100ml
20020368 DER	9/ 2/75	28.0	8.80	7.2	3.2	2.10	0.250	0.036				0.020	0.06		
	9/30/75	26.0	8.20	7.6	3.2	2.27	0.340	0.025				0.020	0.04	0	0
	11/ 4/75	24.0		7.4	4.3	2.65	0.400	0.030				0.030	0.09	0	0
(CONT'D)	12/ 3/75	20.0		9.2	5.1	2.73	0.390	0.031				0.020	0.07	10	0
	1/ 7/76	15.0		10.5	4.5	2.31	0.210			0.010	0.070				
	2/ 3/76	15.0	8.00	9.9	7.3	2.26	0.330			0.020	0.040				
	3/ 2/76	20.0	8.06	9.3	6.0	2.00	0.200			0.020	0.030			0	0
	4/ 6/76	25.0	8.00	9.1	8.5	2.30	0.230			0.010	0.050				0
	5/ 4/76	25.0	8.00	9.4	4.9	1.63	0.190			0.030	0.070				
	6/ 1/76	27.0	9.00	9.1	4.3	2.03	0.050			0.020					
	7/ 6/76	28.0	9.20	8.4	4.0	1.84	0.220			0.020	0.030				
	8/ 3/76	30.0	8.20	7.9	3.4	2.44	0.250			0.000	0.040				
	9/ 7/76	31.0	8.90	10.0	2.4	2.17	0.200			0.010	0.020			0	0
	10/12/76			9.3	6.0	2.26	0.140			0.010	0.000				
	11/ 2/76	22.0	8.70	9.4	3.8	2.43	0.220			0.030	0.040				
20020367 DER	6/ 5/73	28.0	9.20	10.0	3.5	2.54	0.27	0.094				0.01	0.17		
	7/30/74	32.0	8.60	10.0	4.0	2.13	0.02	0.083				0.01	0.06		
20020369 DER	6/ 5/73	27.0	8.90	9.2	3.1	2.64	0.26	0.113				0.01	0.18		
	7/30/74	32.0	8.70	10.3	3.3	1.95	0.02	0.073				0.01	0.06		

SOURCE: STORET
PREPARED BY: HAYES, SUDDERTH & EICHENBERG, INC.

SUMMARY OF WATER QUALITY DATA

LAKE YALE

STATION NO. (SOURCE)	DATE	00010 Temp. (°C)	00400 pH	00300 D.O. mg/l	00310 BOD$_5$ mg/l	00605 Org N mg/l	00610 NH$_3$-N mg/l	00615 00620 Inorg N mg/l	00625 Kjel N mg/l	00671 DisOrthoP mg/l	00665 Tot.P mg/l	70507 OrthoP mg/l	71886 TotP-PO$_4$ mg/l	31501 Tot Col MPN/100ml	31616 Fec Col MPN/100ml
20020371 DER	6/ 4/73 7/30/74	27.0 29.0	8.70	8.5 8.0	1.7 1.6	0.90 0.90	0.18 0.00	0.074 0.061				0.02 0.02	0.17 0.06		
20020372 DER	6/ 4/73 7/30/74	27.0 29.0	8.70	8.8 7.9	1.4 1.5	0.92 0.93	0.15 0.02	0.123 0.061				0.02 0.02	0.17 0.04		

SOURCE. STORET
PREPARED BY. HAYES, SUDDERTH & ETHEREDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE YALE

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD$_5$ mg/l	00605 Org N mg/l	00610 NH$_3$-N mg/l	00630 Inorg N mg/l	00625 Kjel N mg/l	00671 DisOrthoP mg/l	00665 Tot P mg/l	Depth ft	32217 Chl a ug/l
124601	NES	3/14/73	24.5	8.60				0.150	0.16	2.30	0.008	0.042	0	6.3
		3/14/73	25.2	8.60	9.0			0.110	0.16	1.10	0.005	0.019	6	
		3/14/73	24.6	8.60	9.0			0.120	0.16	1.20	0.005	0.015	11	
		9/ 6/73	29.8	8.70	8.6			0.060	0.06	1.50	0.013	0.018	0	90.8
		9/ 6/73	29.3	8.60	8.6			0.050	0.06	1.20	0.017	0.025	10	
		11/ 8/73	22.8	8.90				0.080	0.080	1.40	0.032	0.031	0	15.0
		11/ 8/73	22.8		9.0								2	
		11/ 8/73	22.8	8.80	9.4			0.080	0.080	1.30	0.027	0.033	7	
124602	NES	3/14/73	23.0	8.40				0.140	0.140	0.90	0.004	0.011	0	5.0
		3/14/73	23.0	8.40	8.8			0.140	0.160	0.90	0.008	0.013	6	
		3/14/73	23.8	8.40	8.8			0.130	0.150	1.00	0.005	0.015	12	
		9/ 6/73	29.3	8.60				0.060	0.080	1.60	0.013	0.035	0	21.9
		9/ 6/73	28.8	8.60	8.2			0.050	0.060	1.20	0.023	0.030	5	
		9/ 6/73	28.6	8.50	7.4			0.050	0.070	1.40	0.026	0.035	12	
		11/ 8/73	22.3	8.80				0.080	0.080	1.20	0.020	0.022	0	13.8
		11/ 8/73	22.2	8.90	9.2			0.100	0.070	1.00	0.026	0.032	5	
		11/ 8/73	22.2	8.80	9.2			0.070	0.070	1.10	0.016	0.061	10	

SOURCE: STORET
PREPARED BY: HAYES, [illegible] & ETHERIDGE, INC

SUMMARY OF WATER QUALITY DATA

LAKE YALE

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD_5 mg/l	00605 Org N mg/l	00610 NH_3-N mg/l	00615 00620 Inorg N mg/l	00650 $TotPO_4$ mg/l	00660 $OrthoPO_4$ mg/l	00665 Tot P mg/l	70507 OrthoP mg/l	71886 Tot P-PO_4 mg/l
02238200	USGS	5/4/70	24.8	7.70	1.3	2.6	0.78			0.28	0.23			
		9/30/70	25.0	7.20	2.0	2.6	0.70			0.40	0.23			
		5/11/71	32.0	7.50	8.3	6.3	2.50				0.08			0.17
		9/1/71	29.5	6.60	3.2	4.9	2.10				0.10			0.19
		6/20/72	23.5	7.20	5.4	3.0	1.10	0.020	0.003			0.045	0.012	
		8/31/72	29.0	8.00	3.1	2.4	1.00	0.020	0.005			0.043	0.010	
		5/24/73	26.5	7.30	7.1	1.1	0.81	0.000	0.001			0.000	0.000	
		8/31/73	20.0	7.90	8.0	1.2	1.10	0.000	0.004			0.032	0.012	
		11/7/73	22.0	8.40	6.0A	2.2	1.20	0.000	0.010			0.030	0.007	
		5/14/74	25.0	7.00	5.6A	0.0	1.10	0.090	0.010			0.020	0.010	
		7/29/74	28.6	8.50	7.2A	1.4	0.90	0.010	0.010			0.040	0.010	
		10/10/74	23.0	8.60	7.5A	1.8	1.20	0.050	0.010			0.020	0.020	
		5/7/75	27.0	8.10	6.5	2.2	1.36	0.020	0.040			0.020	0.010	
		8/20/75	31.0	7.30	7.0	1.2	0.99	0.020	0.000			0.020	0.020	
		10/23/75	24.6	7.80	6.5A	1.3	0.93	0.030	0.000			0.010	0.010	
		5/4/76	24.5	8.10	9.2A	1.5	0.88	0.020	0.010			0.020	0.010	
		7/27/76	30.5	8.60	7.1A	3.2	0.85	0.020	0.010			0.030	0.020	
		9/15/76	25.5	8.70	7.4	0.3	0.98	0.010	0.010			0.020	0.010	

A= AVERAGE OF MEASUREMENTS AT SEVERAL DEPTHS

SOURCE. STORET
PREPARED BY: HAYES, SUDDENTH & ETHERIDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE HARRIS

STATION NO. (SOURCE)	DATE	00010 Temp. (°C)	00400 pH	00300 D.O. mg/l	00310 BOD$_5$ mg/l	00605 Org N mg/l	00610 NH$_3$-N mg/l	00615 00620 Inorg N mg/l	00625 Kjel N mg/l	00671 DisOrthoP mg/l	00665 Tot.P mg/l	70507 OrthoP mg/l	71886 TotP-PO$_4$ mg/l	31501 Tot Col MPN/100ml	31616 Fec Col MPN/100ml
20020375 DER	6/ 5/73	27.0	8.80	8.6	3.0	2.12	0.23	0.087				0.02	0.18		
	7/30/74	30.0	8.40	8.2	2.2	1.43	0.03	0.064				0.01	0.05		
20020376 DER	6/ 5/73	27.0	8.90	8.0	2.5	1.97	0.20	0.116				0.02	0.18		
	7/30/74	30.0	8.20	8.7	1.9	1.43	0.03	0.066				0.01	0.04		
	5/11/75	23.5	8.30	8.6	2.8	1.65	0.49	0.010				0.03	0.07	0	0
	10/12/76			8.5	2.4	1.14	0.07				0.04				
20020377 DER	6/ 5/73	27.0	8.80	8.3	2.0	2.0	0.23	0.114				0.02	0.18		
	7/30/74	30.0	8.50	9.1	2.2	1.41	0.02	0.661				0.01	0.03		

SOURCE, STORET
PREPARED BY, HAYES, SUDDERTH & ETHEREDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE HARRIS

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD_5 mg/l	00605 Org N mg/l	00610 NH_3-N mg/l	00615 00620 Inorg N mg/l	00650 $TotPO_4$ mg/l	00660 $OrthoPO_4$ mg/l	00665 Tot P mg/l	70507 OrthoP mg/l	71886 Tot P-PO_4 mg/l
02237520	USGS	4/29/68	28.0	7.30	8.2					0.11				
		5/5/69	26.0	6.90	8.3					0.05				
		5/10/70	27.0	6.90	7.9		1.20			0.05	0.03			
		5/12/71	28.0		8.0		1.60				0.05			0.10
		5/4/72	25.5		6.2									
		4/13/73	23.0		6.0	3.4								

SOURCE, STORET
PREPARED BY, HAYES, SUDDERTH & ETHERIDGE, INC.

SUMMARY OF WATER QUALITY DATA

LAKE HARRIS

STATION NO.	SOURCE	DATE	00010 Temp. (°C)	00400 pH	00300 D. O. mg/l	00310 BOD_5 mg/l	00685 Org N mg/l	00610 NH_3-N mg/l	00620 NO_3-N mg/l	00650 $TotPO_4$ mg/l	00660 $OrthoPO_4$ mg/l	00665 Tot P mg/l	70507 OrthoP mg/l	71886 Tot P-PO_4 mg/l
CENTER OF NE END	LAKE CO. PCD	10/6/75	27.0	8.5	7.6		1.56	0.01L	0.01L	0.01L	0.01L			
		8/11/76	29.0	8.6		1.8	1.14	0.01L	0.01L	0.01L	0.01L			
		4/12/77	21.0	8.7	9.7	2.8	1.47	0.01L	0.04	0.08	0.01L			
CENTER	LAKE CO. PCD	10/6/75	27.0	8.5	7.4		1.50	0.01L	0.01L	0.01L	0.01L			
		3/30/76	23.0	8.8	10.4		1.39	0.36	0.01L	0.10	0.01L			
		8/11/76	29.0	8.5		1.2	1.08	0.01L	0.01L	0.01L	0.01L			
		4/12/77	21.0	8.4	9.7	2.8	1.49	0.01	0.04	0.08	0.01L			
CENTER OF WEST END	LAKE CO. PCD	10/6/75	27.0	8.2	7.8		1.50	0.01L	0.01L	0.01L	0.01L			
		8/11/76	29.0	8.6		1.8	1.06	0.01L	0.01L	0.01L	0.01L			
		4/12/77	21.0	8.6	9.7	2.8	1.47	0.01L	0.05	0.08	0.01L			

L= LESS THAN

SOURCE: LAKE COUNTY POLLUTION CONTROL DEPARTMENT
PREPARED BY HAYES, SUDDERTH & ETHERIDGE, INC.

APPENDIX B

ENGINEERING DESIGN PLAN AND COST BREAKDOWN

(Sections 9 and 11 of RSB&W's
Preliminary Engineering Report)

SECTION 9

PROPOSED FACILITIES TO IMPLEMENT PLAN

9.01 GENERAL

A. Pumping Equipment

During the course of this project, two pumping facilities will be required during the drawdown and holddown phases and three pumping facilities will be required during the refill phase. Consequently, the most important equipment required for this project will be the pumps. This pumping equipment must be capable of transferring large volumes of water from a lower elevation to a higher elevation at low discharge pressures.

One pump manufacturer provides hydraulically driven axial flow pumps with capacities up to 50,000 gallons per minute (gpm). The equipment is very simple to operate, relatively easy to maintain and flexible. Pumps can be either mounted on tires for mobile operation or on skid mounts for installation on a pad. Skid mounted units will be required for this project in order to achieve the higher discharge pressures required. Pumps of this type are well suited for this project.

B. Control Stations

The central control station will be established at Apopka-Beauclair Canal Lock and Dam. The central control station will serve as the command post during the entire project, directing and coordinating the construction and operation of all facilities. This site is centrally located and well accessed. Telephone and electricity are readily available.

In addition, a citrus irrigation control station will be established in the Winter Garden area. This station will direct and coordinate the mobile irrigation equipment and irrigation wells.

C. Communication System

During the course of the entire project, communication between the various sites will be very important. Telephones will be installed at the sites where telephone service is readily available. Remote sites (those which are not readily accessable by telephone service) will be linked to the central control station by two-way radio.

D. Protection of Property

The protection of people and animals from dangerous areas at the several sites as well as providing against vandalism are also important considerations on a project of this magnitude. Temporary fences will be required at the sites which are easily accessible to the general public to keep the curious away from equipment and excavations. Vandalism should not be a serious concern as each site will require full time supervision. All areas of concern will be posted to make the public aware of the dangers present.

During certain phases of the project considerable flow will be conveyed by the canals interconnecting the lakes downstream from Lake Apopka. The velocities created by these conditions may make it difficult or impossible to operate boats in the canals, especially in the narrower areas. Therefore, these areas will require more intensified boat patrol to restrict boat traffic when conditions are dangerous and to be available should an emergency arise. Posting of the various waterways to warn boaters of impending danger will also be necessary.

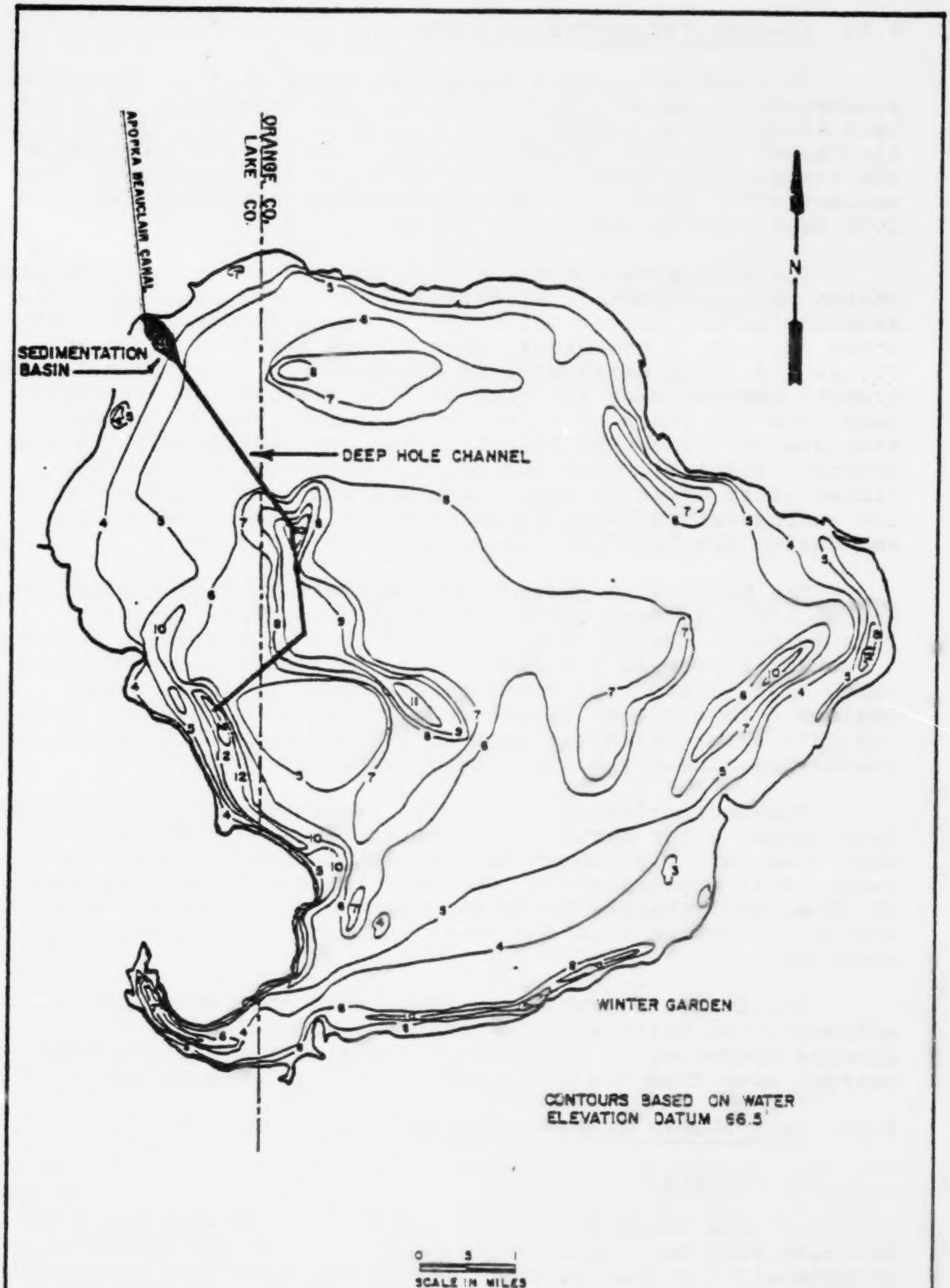
In this Section of the report, each major facility will be described in detail to acquaint the reader with the major considerations relative to the sites.

9.02 LAKE APOPKA DEEP HOLE CHANNEL

The proposed method for draining Lake Apopka to 58 feet MSL includes the hydraulic dredging of a trapezoidal channel which will connect "deep hole" areas in the lake and convey water to the intake sump of the main pump station at the south end of the Apopka-Beauclair Canal. Based on a maximum velocity of flow in the dredged channel of 0.5 feet per second (fps) to prevent entrainment of any surrounding muck material, and an average volumetric flow rate of 500 MGD, the channel will be approximately 5 feet deep, 200 feet wide at the base, and have side slopes of about 15:1. The main channel will be approximately four miles long. The route of the deep hole channel is shown in Figure 9-1. It is estimated that approximately two million cubic yards of material will have to be dredged in constructing the channel.

The method of channel excavation will involve the use of floating hydraulic dredges equipped with augers and pumps to discharge material back into the lake as far away as 2,000 feet by a floating discharge pipe. This excavated material will settle to the bottom of the lake and receive the same consolidation treatment as the rest of the lake bottom during drawdown and holddown.

220<


APOPKA BEAUCLAIR CANAL
ORANGE CO.
LAKE CO.
N
SEDIMENTATION BASIN
DEEP HOLE CHANNEL
WINTER GARDEN
CONTOURS BASED ON WATER ELEVATION DATUM 66.5'
0 .5 1
SCALE IN MILES
NOTE: BASE MAP OBTAINED FROM REFERENCE 1

Location of deep hole channel and in-lake sedimentation basin

FIGURE 9-1

9.03 IN-LAKE SEDIMENTATION BASIN

In order to protect downstream water quality, an in-lake sedimentation basin will be used to remove sediment from the Lake Apopka water before it is pumped out of Lake Apopka and discharged into the Apopka-Beauclair Canal. The location of the in-lake sedimentation basin is shown in Figure 9-2. The sedimentation basin will be approximately 4000 feet long and 2000 feet wide at its widest point.

The sedimentation basin will be dredged to a bottom elevation of approximately 48 feet MSL (about 13 feet below the existing bottom elevation) with 15:1 side slopes. A typical cross section at the widest part of the basin is shown in Figure 9-3. The basin will be dredged by a floating hydraulic dredge; dredged muck and clay will be disposed of laterally away from the basin by floating discharge lines. The sand encountered during the last 4.5 feet of dredging will be discharged relatively near the basin. This will result in a firmer crust after consolidation and aid in the operation of the sedimentation basin during the end of the drawdown phase and during the holddown phase.

The basin will provide an average detention time of 20 hours, and a surface loading rate of 90 gallons/day/ft^2. This surface loading rate is higher than suggested in Section 7, so as to provide a buffer against any unforeseen problems which might arise with basin operation or influent water quality. This higher detention time and lower surface loading rate also avoids the need to utilize chemicals to aid sedimentation, thereby minimizing operational costs.

The sedimentation basin will remain submerged until the Lake Apopka water surface is lowered below 62 feet MSL. At that time, the sedimentation basin will appear. When the water level approaches 58 feet MSL, there will be four feet of freeboard, thereby minimizing wind effects and agitation during the period when the worst influent water quality is expected.

Settled solids which accumulate in the bottom of the sedimentation basin will be removed by floating hydraulic dredges operating in the basin. These solids will be discharged away from the basin and allowed to consolidate.

9.04 LAKE APOPKA PUMPING STATION

A. General

The first of the two drawdown/holddown pumping facilities will be located on the Apopka-Beauclair Canal, approximately 580 feet north of the entrance to Lake Apopka. A cofferdam will be build across the Apopka-Beauclair Canal to support the necessary pumping equipment. Water will be pumped out the intake sump on the Lake Apopka side of the cofferdam, lifted over the cofferdam and discharged into the Apopka-Beauclair Canal. The Lake Apopka pumping station is shown in Figure 9-4.

B. Approach Channel

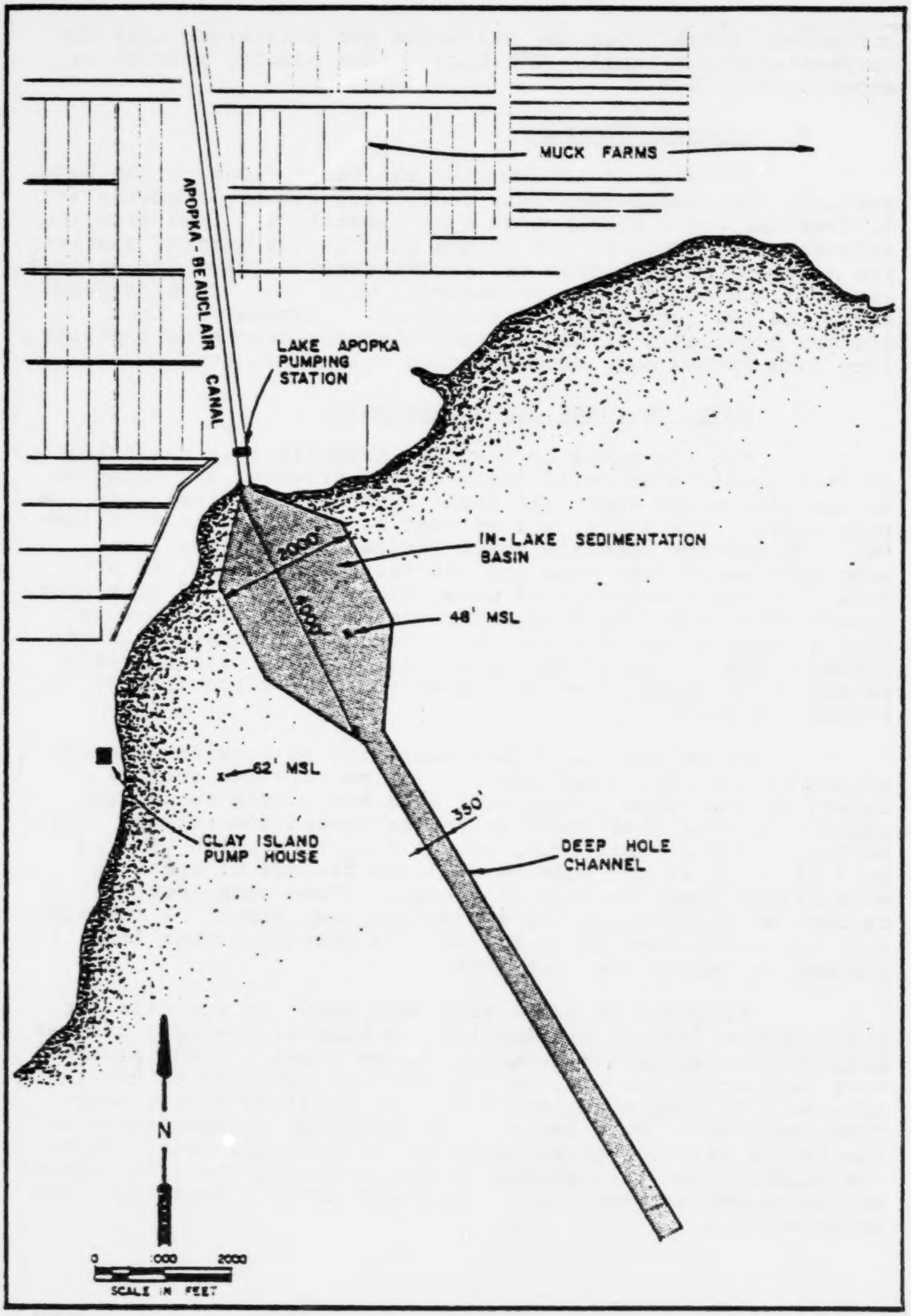
In order to accommodate the large flows to the pump station, the Apopka-Beauclair Canal will require dredging to 50 feet MSL for a distance of approximately 580 feet from the sedimentation basin to the intake sump at the pumping station. The existing canal bottom is approximately 60 feet MSL so that about 25,000 cubic yards of material will need to be dredged along the 130 foot width of the canal. Disposal of the dredged material will be via long floating discharge conduits into Lake Apopka away from the deep hole canal area.

C. Sump, Weir and Protective Nets

For the pumps to function properly over the range of lake levels which will occur during drawdown and holddown, an adequate water depth (12 feet) must be maintained over the pump inlet. Therefore, a sump must be excavated to 44.5 feet MSL. To provide adequate space for ten inlet pipes, this sump must be 20 feet wide and 100 feet long. Also, to provide a smooth transition of water flow from the 150 foot long intake weir, the sump design includes a transition zone so that a total of about 3,800 cubic yards of excavation is required. The bottom of the sump will be lined with approximately 3,700 square feet of riprap to prevent scouring of bottom sediments.

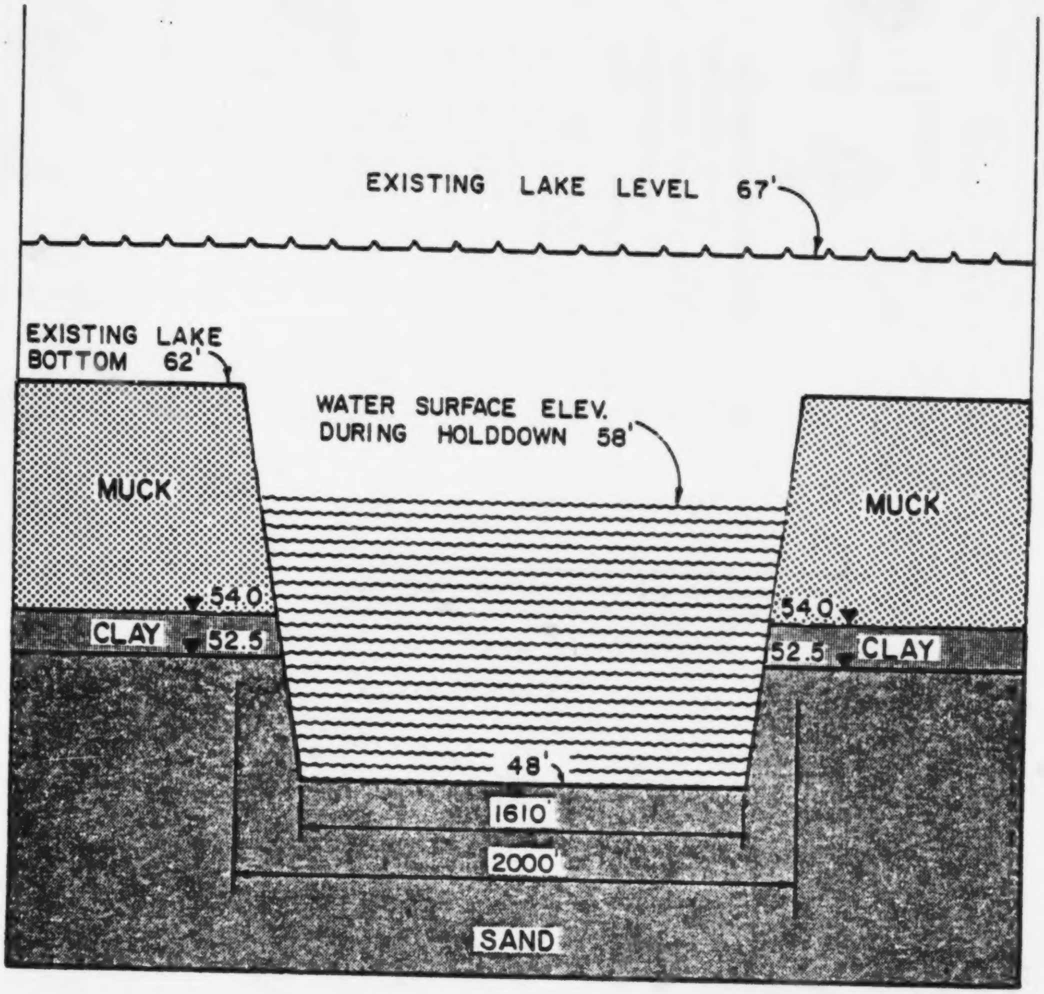
An adjustable intake weir will be located just upstream of the pump sump, and will allow only the surface waters at that time (which will have the lowest suspended solids) to flow into the sump and be pumped downstream. This weir will use 15 feet long, wooden stop logs which will be held in place at the ends between the flanges of vertical, wide flange steel members (H beams). These stop logs will be removed as necessary as the water level drops. A catwalk will be constructed above the weir to provide access for workmen to remove the stop logs.

Attached to the intake weir shall be supports for 1,500 square feet of wildlife net to keep alligators, turtles, etc. from entering the sump and intake pipes. A 400 square foot vegetation net will be located just upstream of the intake weir to keep hyacinths and other floating plants away from the pumps. This net will be supported independently of the intake weir by wooden posts driven into the canal bottom. The wildlife net will extend to the bottom of the canal whereas the vegetation net would only reach about 2 feet below the water surface.


MUCK FARMS
APOPKA - BEAUCLAIR CANAL
LAKE APOPKA PUMPING STATION
IN-LAKE SEDIMENTATION BASIN
2000'
4000'
48' MSL
62' MSL
350'
CLAY ISLAND PUMP HOUSE
DEEP HOLE CHANNEL
N
0
1000
2000
SCALE IN FEET

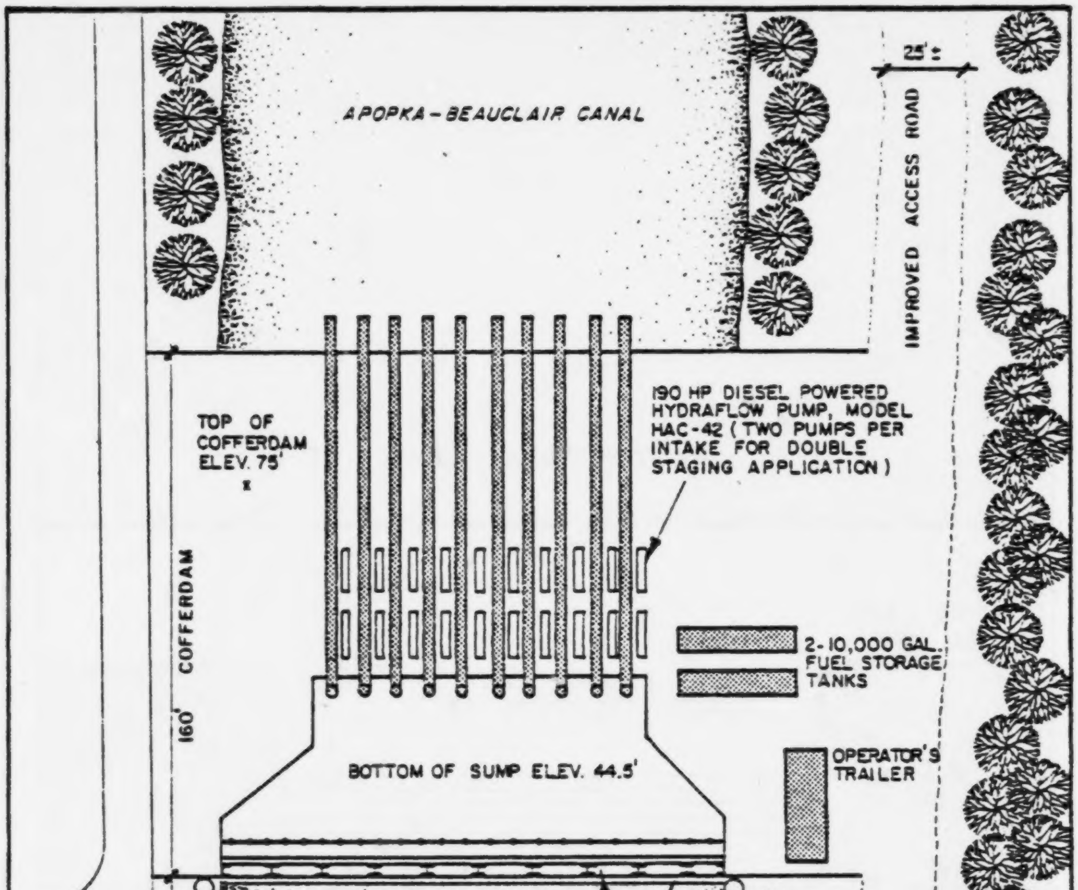
In-lake sedimentation basin

FIGURE 9-2


EXISTING LAKE LEVEL 67'
EXISTING LAKE BOTTOM 62'
WATER SURFACE ELEV. DURING HOLDDOWN 58'
MUCK
MUCK
54.0
54.0
CLAY
52.5
52.5
CLAY
48'
1610'
2000'
SAND

Typical cross section of the in-lake sedimentation basin

FIGURE 9-3


APOPKA-BEAUCLAIR CANAL
25'±
IMPROVED ACCESS ROAD
TOP OF COFFERDAM ELEV. 75'
190 HP DIESEL POWERED HYDRAFLOW PUMP, MODEL HAC-42 (TWO PUMPS PER INTAKE FOR DOUBLE STAGING APPLICATION)
160' COFFERDAM
2-10,000 GAL. FUEL STORAGE TANKS
OPERATOR'S TRAILER
BOTTOM OF SUMP ELEV. 44.5'
150' ADJUSTABLE WEIR WITH WOODEN STOP LOGS
WILDLIFE NET
VEGETATION NET
EXIST. CANAL ELEV. =60'± TO BE DREDGED TO 50'
FLOW
N
1" = 50'

226<

Lake Apopka pumping station.

FIGURE 9-4

D. Cofferdam

At the end of the holddown period, the water level in Lake Apopka will be at 58 feet MSL. The existing ground near the pump station site is about 69 feet MSL. A cofferdam will be build across the width of the canal and tie into the existing berm along both banks. The cofferdam will be about 15 feet high, with the top of the dam at 75 feet MSL. The width of the cofferdam will be 160 feet in order to provide sufficient space for pumps, discharge pipes, and vehicle access. An estimated 9,000 cubic yards of fill material will be required to build the dam.

E. Access

A private farm road along the east side of the canal will be used for access to this site. The road must be upgraded to handle heavier and wider construction vehicles. Upgrading will consist of widening the road to 25 feet, providing parking and a turn-around at the site, and adding sand or other suitable fill material to wet areas and low spots. At the conclusion of the project, the road could either be restored to its original condition or left as modified at the owner's discretion.

F. Pump Units

The pumps are designed to function during the drawdown and holddown periods. The worst design condition occurs at the end of the drawdown period when water is being pumped at a rate of 500 MGD from an elevation of 58 feet MSL to an elevation of 75 feet MSL on top of the cofferdam.

To deliver 500 MGD against a total dynamic head of 20 feet, double staging of pumps will be required. A total of twenty 190 HP diesel powered Hydraflo 42-inch intakes will have two hydraulically powered axial flow impellers mounted in the intake. Under normal operating conditions only eight of the intakes will be operated, with the remaining two intakes and four diesel powered pumps serving as stand-by units. The 190 HP diesel motor units which supply pressure to the hydraulically driven axial flow pumps will be mounted on skids and placed on timber cribbing on the cofferdam to provide stability against vibration and movement.

The pumps will take suction from the sump and discharge flow directly into the Apopka-Beauclair Canal north of the cofferdam. All pump discharge pipes will cross under the access road and discharge into the Apopka-Beauclair Canal. Provisions will be made to monitor the water being pumped by installation of a sample line.

G. Control Trailer

A mobile trailer will be installed at the site to provide housing for the operators. The trailer will also provide housing for radio equipment, records, maintenance tools, etc.

H. Fuel Storage

Two 10,000 gallons fuel storage tanks will be required at the cofferdam to supply the diesel pumps with fuel. It is estimated that with the pumps running on a 24-hour basis, the fuel tanks will need to be replenished once every week by tank truck deliveries.

9.05 APOPKA-BEAUCLAIR CANAL

A. Silt Removal

While the velocities in the Apopka-Beauclair Canal during drawdown will not erode the protected or unprotected areas of the adjacent dikes, they may be sufficient to convey silt from the existing canal bottom and deposit it in Lake Beauclair. Preliminary survey indicates that deposits of transportable silt are located below the Lock and Dam on the Apopka-Beauclair Canal, especially in the area bounded by the railroad bridge and Lake Beauclair. Dredging the canal in this area will be required to remove the silt and prevent its movement into Lake Beauclair. A hydraulic dredge will be utilized in this area to remove the silt and either discharge it onto the side slopes of the dike away from the canal, or discharge it into trucks for disposal elsewhere. It is expected that a combination of the two methods will be used as there will be some areas where spreading silt on the dike slopes may not be possible due to the presence of developed private property. However, trucking silt should be kept to a minimum to control costs.

B. Dike Protection

During the drawdown phase when the maximum quantity of water is pumped from Lake Apopka to the downstream side of the cofferdam in the Apopka-Beauclair Canal a maximum water surface below the cofferdam of 68 feet MSL can be expected. Existing dike elevations from the Lock and Dam to Lake Apopka vary between 65 feet MSL and 70 feet MSL. Therefore, protection of the dikes will be required in this area to provide a minimum freeboard of two feet. The dike elevation would be brought up to 70 feet MSL at Lake Apopka and to 69 feet MSL upstream of the Lock and Dam. Existing dike elevations in the immediate vicinity of the Lock and Dam are primarily above 70 feet MSL, however, some areas vary around 68 feet MSL. Fill material used to raise dike elevations will be locally available coarse sand.

Maximum water surface elevations below the Lock and Dam during the various phases will be about 64 feet MSL at

228<

the Lock and Dam and 63.5 feet MSL at Lake Beauclair. This will occur during the holddown phase when the elevation of Lake Beauclair is increasing for storage purposes. Existing dike elevations in this area vary from 70 feet MSL to 65 feet MSL. It would appear that only scattered areas will require fill to raise the dike to 66 feet MSL, although more accurate field data will be required in order to verify this.

In the area immediately upstream and downstream of the Lock and Dam considerable turbulence will be created by the water cascading over the dam during the drawdown, holddown, and refill phases. Dike and canal bottom protection will be required in these areas to prevent scouring action created by the turbulent water. One method which could be employed is to use bagged concrete and/or bagged sand to line the channel in the immediate vicinity of the Lock and Dam. The bags would be removed after the refill phase. There are two highway, one railroad and one farm bridge over the Apopka-Beauclair Canal. The bridges are primarily supported by wooden piles. The maximum velocity which will be created in the canal during the project is not expected to exceed about 2 fps although there may be locally higher velocities in the vicinity of bridge piles. The exact method and degree of protection for the bridge supports can be ascertained during the final design phase. It has been assumed that sheeting, bagged sand and/or bagged concrete will be placed around all bridge supports to protect the material around them from scouring excessively.

9.06 DORA CANAL

During the drawdown and holddown phases, pump facilities will be required at the entrance of the Dora Canal from Lake Dora. Since the canal has limited capacity to transmit flow, a portion of the water will be pumped into an 84-inch diameter by-pass pipeline and transmitted to Lake Eustis. The Dora Canal facilities are shown in Figure 9-5.

During the refill phase, the pumps will be relocated to Lake Eustis refill pumping station and the process reversed. Again, due to the hydraulic limitations of Dora Canal, a portion of the refill water will be back pumped into the 84-inch diameter pipeline and transmitted to Lake Dora.

A. Lake Dora Drawdown Pumping Station

1. Inlet Sump

Pumping equipment will require a minimum nine feet of water above the pump inlet (see Figure 9-6). Therefore, a sump will be excavated at the shoreline 16 feet wide and 56 feet long to house the seven pump suctions and to provide for adequate water storage during pumping operation.

Sheeting will be driven around the proposed sump to create a box. The top of the sheeting will be cut off at about 62 feet MSL to form a weir which will allow water to spill into the sump during the pumped drawdown and holddown phases, preventing bottom deposits from entering the sump. During the refill phase the weir will prevent excessive scouring of the lake bottom in the immediate vicinity of the by-pass pipe by allowing the energy to dissipate within the confines of the sump.

The sump will be excavated to an elevation of approximately 52 feet MSL, or about five feet below the existing adjacent lake bottom. Large riprap will be placed in the bottom of the sump to prevent erosion of the bottom. Riprap would be locally available precast concrete planks or large pieces of highway or building concrete from demolition projects. Similarly, riprap will be required outside the sump adjacent to the sheeting to prevent scouring. A vegetation net will be installed immediately upstream of the sump as well as the wildlife net to prevent floating vegetation, fish and alligators from entering the sump.

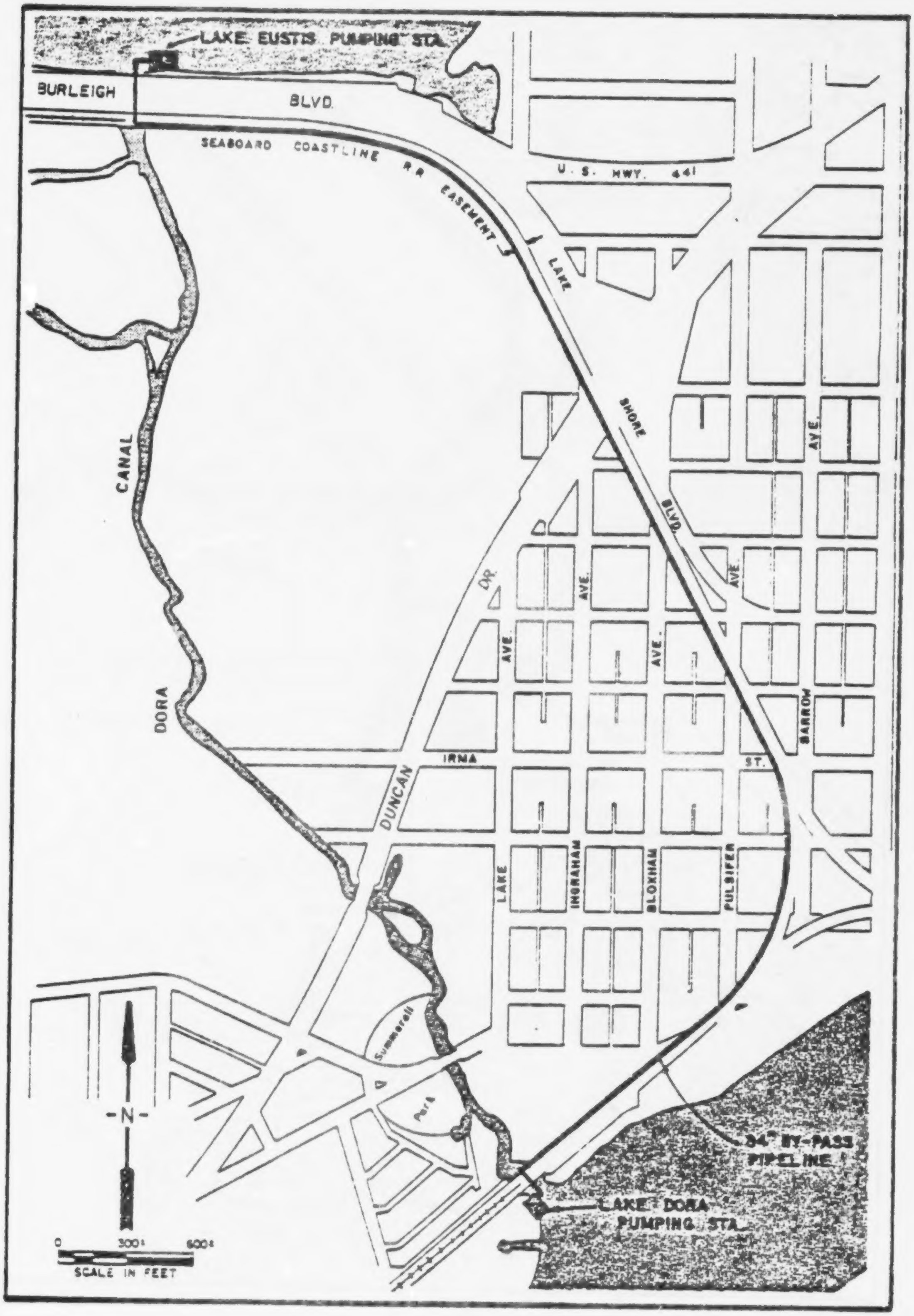
2. Pump Units

Six electric drive 30-inch Hydraflo axial flow pumps, and one standby pump, will be required at the site for the pumped drawdown and holddown phases. The total capacity of the station is designed to pump 156,000 gpm against a total dynamic head of 20 feet. The pumps will be skid mounted units which can be mounted on the ground, or may require the construction of a timber pad to provide a more secure foundation. Timber would be preferred over concrete as it can be salvaged at the end of the project, whereas the concrete would require demolition in order to restore the property to its original condition.

The pumps will take suction from the sump and discharge the flow to a common discharge header. The header would in turn feed into an 84-inch diameter steel lined corrugated metal transmission by-pass line to Lake Eustis. Provision will be made to monitor the water being pumped by installation of a sample line on the discharge header.

A transformer substation will be required at the site to reduce line voltage for the seven, 200 HP electric motors. The use of electric motors in this populated area should keep noise levels below an objectionable threshold value. If, however, the site requires the installation of an accoustical system to control noise, accoustical panels of precast concrete or other suitable material can be installed around the pumps to dampen the sound. A roof may also be required over the pumps to control noise and provide a dry area for maintenance and repair of equipment. Whatever work is done in this regard will be simply due to the temporary nature of the station.

Pumps will be operated manually at sufficient

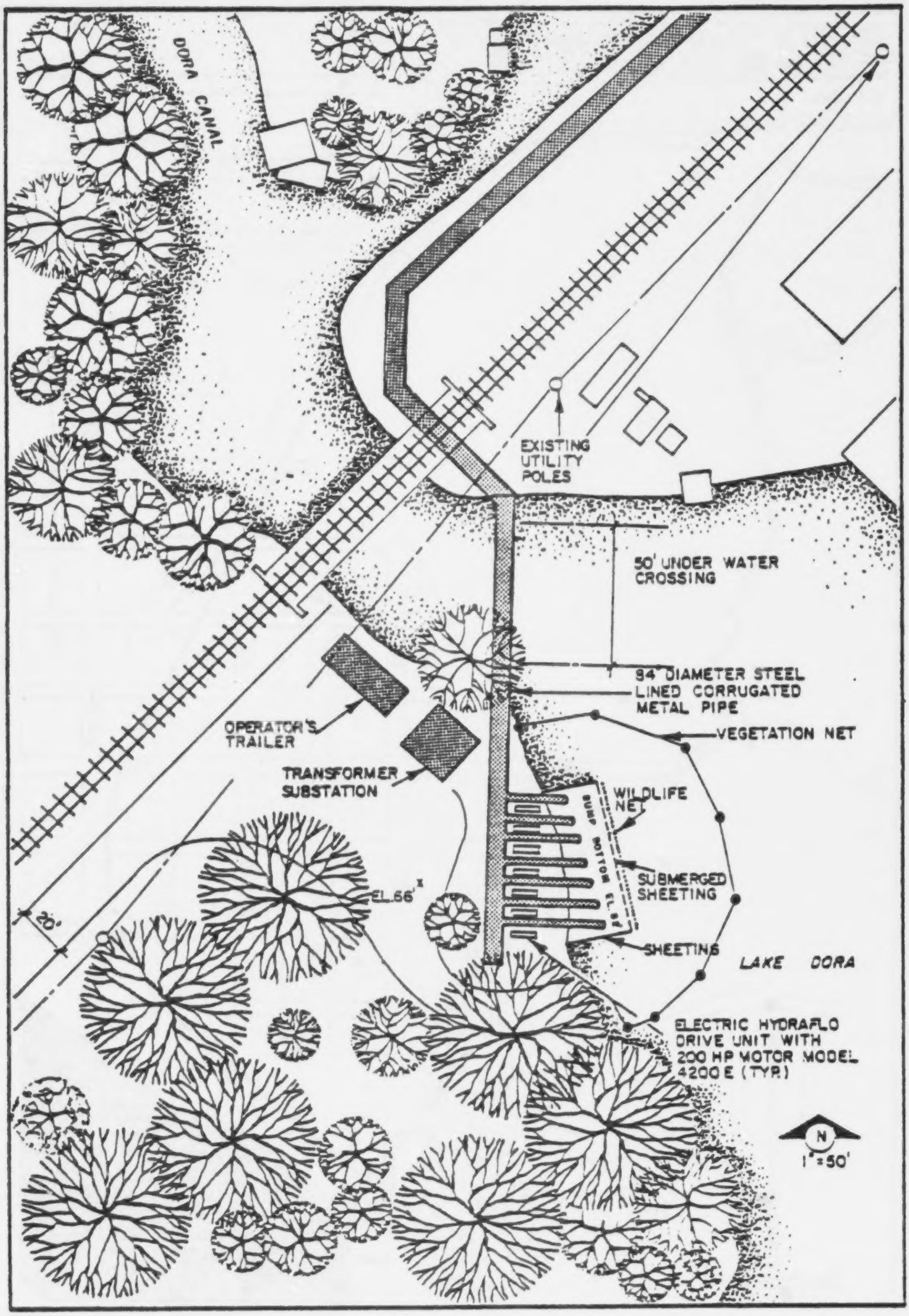

LAKE EUSTIS PUMPING STA.
BURLEIGH BLVD.
SEABOARD COASTLINE R.R. EASEMENT
U.S. HWY. 441
LAKE SHORE DRIVE
DORA CANAL
DUNCAN DR.
IRMA ST.
AVE.
AVE.
AVE.
AVE.
AVE.
LAKE
INGRAHAM
BLOXHAM
PULSIFER
BARROW
Summerall
Park
34" BY-PASS PIPELINE
LAKE DORA PUMPING STA.
N
0
300'
600'
SCALE IN FEET

Dora canal facilities

231<

9-8 (a)

FIGURE 9-5


DORA CANAL
EXISTING UTILITY POLES
50' UNDER WATER CROSSING
84" DIAMETER STEEL LINED CORRUGATED METAL PIPE
VEGETATION NET
OPERATOR'S TRAILER
TRANSFORMER SUBSTATION
WILDLIFE NET
SUMP BOTTOM EL.
SUBMERGED SHEETING
EL.66'
20'
SHEETING
LAKE DORA
ELECTRIC HYDRAFLO DRIVE UNIT WITH 200 HP MOTOR MODEL 4200 E (TYP.)
N
1" = 50'

Lake Dora pumping station

9-8(b)

FIGURE 9 - 6

rates to convey adequate quantities of water during pumped drawdown and holddown phases from Lake Dora to Lake Eustis without raising the level of Lake Dora above 64 feet MSL and thereby prevent flooding both in Lake Dora and Dora Canal. The water depth in Lake Dora will be obtained from a gage and the information relayed periodically to the central control station for overall operation control.

An alarm system will also be installed which will be activated if the water level rises above a preset value. The alarm signal can either be initiated locally and/or conveyed to the central control station should the operator not be available to take corrective action.

3. Control Trailer

A mobile trailer will be installed at the site to provide housing for the operators. The trailer will also provide housing for radio equipment, records, maintenance tools, etc.

4. Access Road

Access to the site will be over a road which will be constructed by extending the existing road serving residences to the southwest of the pump station site. Some trees will require removal for construction of the road and other facilities at the site. A course sand road of sufficient capacity to handle heavy vehicles will be adequate, and will be rather easy to remove at the completion of the project.

B. Transmission By-Pass Line

A by-pass pipeline will be required to convey flow from the Lake Dora pumping station to Lake Eustis during drawdown and holddown phases of operation, and to convey flow from the Lake Eustis pumping station to Lake Dora during the refill phase. The maximum flow of water to be by-passed is estimated to be about 325 cubic feet per second (cfs). Flow of this magnitude will require the use of 84-inch diameter, low-pressure steel lined corrugated metal pipe.

As shown on Figure 9-5, the pipe will proceed from the Lake Dora pumping station site, across the Dora Canal passing under the canal bottom, thus keeping the canal open to boating. The pipe will then proceed along the north bank under the railroad bridge. There is sufficient clearance to install the pipe between the bridge pilings northeast of the canal. Once under the railroad bridge the pipe will proceed along the railroad right-of-way to Irma Street in Tavares. At this location the pipe will be installed in an excavated trench under the street. Utilities in the street will be avoided where possible, and relocated if it is not possible to adjust the grade of the 84-inch pipe to avoid them.

After crossing Irma Street, the pipe will continue to proceed along the railroad right-of-way to Duncan Drive (Highway 19). The pipe will also be placed in an excavated trench at this location. The pipe will continue along the railroad right-of-way (Dora Canal side) to the railroad bridge at U.S. Highway 441 in the vicinity of the canal outlet. The pipe will pass under the railroad and highway bridges and terminate at a sump constructed for the purposes of energy dissipation and pump suction. Total length of the by-pass pipeline will be approximately 7000 feet.

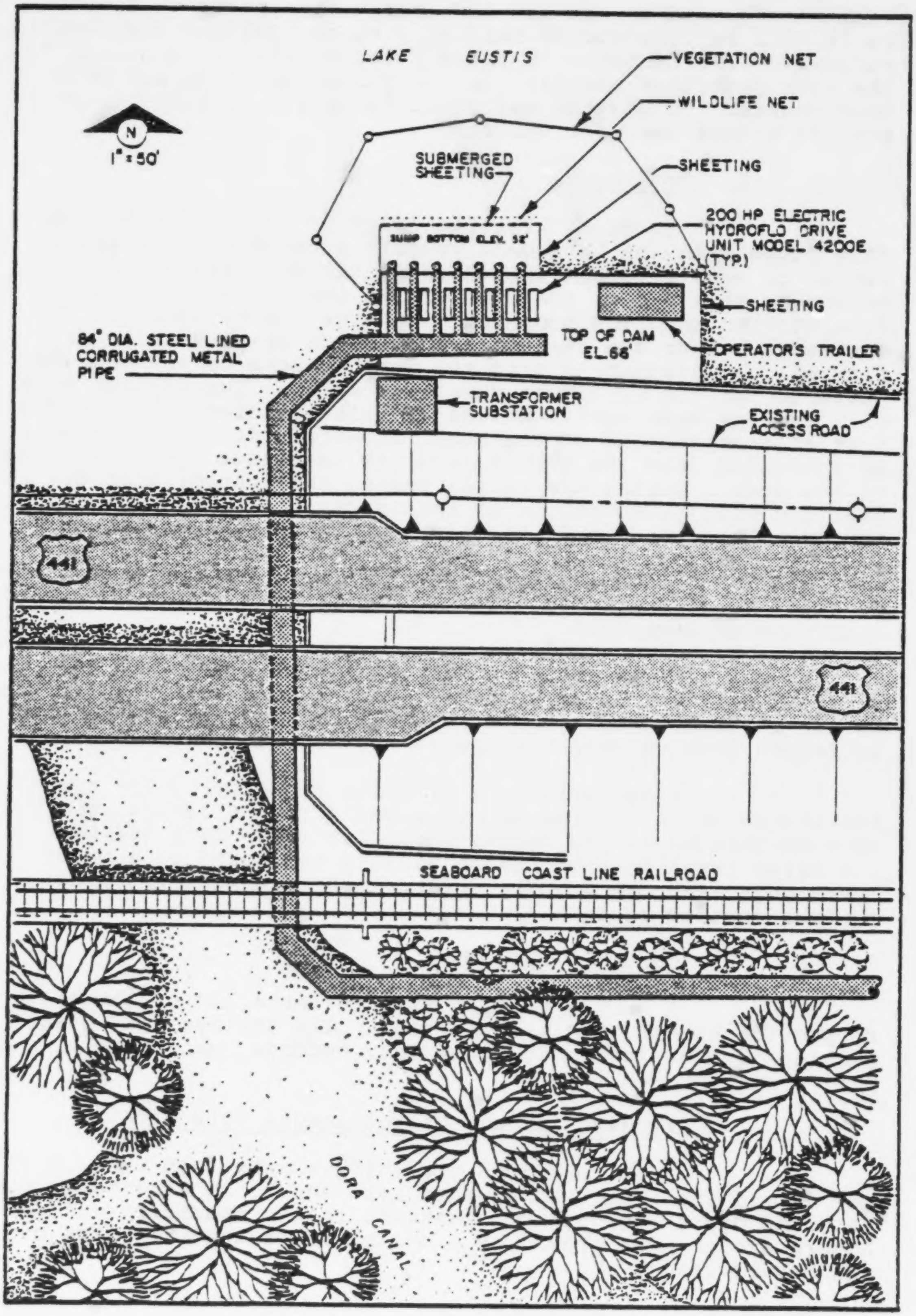
Most of the by-pass pipeline route will be accessible by a temporary access road to be constructed along side the pipe. In some areas, however, this will not be required or even feasible. At the beginning of the pipeline after crossing under the railroad bridge at the south entrance to the Dora Canal, it will be necessary to install the 84-inch diameter pipeline by working from a floating barge for a distance of approximately 400 feet along a shallow canal parallel to the railroad right-of-way. Installation of pipeline north of the Seaboard Coast Line Railroad along the spur which goes through Tavares and is utilized only for the storage of railroad cars, can be accommodated by working from the existing railroad embankment. Along the last 2,000 feet of the pipeline approaching Lake Eustis, an existing utility line at the toe of the railroad embankment will have to be relocated. Upon termination of the project, the pipe will be removed and the project area restored to its original condition.

The elevation of the pipe at either end (Lake Eustis or Lake Dora) will be approximately 65 feet MSL. The high point of the pipe will occur between Duncan Drive and Irma Street at 70 feet MSL. Therefore, the pipe will be essentially a pressure pipe over its entire route and for this reason lateral support will be required, especially at changes of direction, to prevent the pipe joints from pulling apart. It it proposed to provide lateral protection for the straight alignment sections by installing the pipe in a trench excavated up to mid-diameter of the pipe. Where there are abrupt changes in direction the pipe will be more securely tied down by concrete thrust blocks, restrained joints, or sheeting. Sensors will be installed regularly along the pipeline to detect any breaks which might occur. In the event of a break, an alarm will sound and the pumps will be stopped.

C. Lake Eustis Pumping Station

1. Inlet Sump

The energy dissipater constructed at the refill pump station site near Lake Eustis will be converted to a sump for the refill pumps (see Figure 9-7). The 84-inch pipe will be removed from the sump and seven pumps will be installed with their intake pipes installed in the sump. No additional work


LAKE EUSTIS
N
1" = 50'
VEGETATION NET
WILDLIFE NET
SUBMERGED SHEETING
SHEETING
200 HP ELECTRIC HYDROFLO DRIVE UNIT MODEL 4200E (TYP.)
SUMP BOTTOM ELEV. 52'
SHEETING
TOP OF DAM EL.66'
OPERATOR'S TRAILER
84" DIA. STEEL LINED CORRUGATED METAL PIPE
TRANSFORMER SUBSTATION
EXISTING ACCESS ROAD
441
441
SEABOARD COAST LINE RAILROAD
DORA CANAL

Lake Eustis pumping station

9-10(a)

FIGURE 9 - 7

will be required to convert the energy dissipater to a sump as it will be constructed initially to be used for the dual purposes. The features of the structure will be identical to the sump described earlier for the pumped drawdown and hold-down phases. Vegetation and wildlife nets will also be installed around the weir and sump.

2. Pump Units

The seven electric drive 30-inch Hydraflo axial flow pumps from the Lake Dora pumping station will be transferred to this site and installed either directly on the ground or on a pad on the bank of the lake. Each pump will take suction from the sump and discharge its contents to the discharge header and 84-inch transmission by-pass line. The flow will be discharged into the sump at Lake Dora which was utilized for the Lake Dora pumping station. The 84-inch pipe will require some modifications at this location. During the initial construction of the sump, a section 84-inch pipe will be installed from the ground level to terminate near the bottom of the sump. During the refill phase, the transmission by-pass pipeline will be connected to this section of pipe so that pumped refill water will terminate in an energy dissipater.

Provisions will be made for obtaining a sample of water being pumped in order to monitor the quality of water returning to Lake Dora.

It is anticipated that adequate electric service can be extended to provide power at this location for the pumps. A transformer substation will be required at the site to reduce line voltage for the seven, 200 HP electric motors.

Pumps will be controlled manually by the operator according to information received from the central control station located at the Apopka-Beauclair Canal Lock and Dam. The water level in Lake Eustis will be monitored by a water level gage each day and the information transmitted to the central control station.

3. Control Trailer

A mobile trailer will be installed on the site to provide housing for the operator. The trailer will also provide housing for radio equipment, records, maintenance tools, etc.

4. Access Road and Miscellaneous Site Work

An access road presently exists from U. S. Highway 441 to the site. This paved road should be acceptable for trucking operations during construction and operation phases. A turn around area should be provided where space permits off the access road.

There presently is not sufficient land at the site to hold all of the facilities required. Additional land will be provided by sheeting a short distance into the lake and filling in behind the sheeting. After termination of the project, the area will be completely restored.

D. Protection in the Dora Canal

There exists two railroad bridges and two highway bridges over the Dora Canal. During the drawdown, holddown, and refill phases higher velocities will occur in the canal than normal. While the bridges do appear to have in general adequate riprap protection of the abutments, the piling supports may require some protection to minimize scouring of material around the piles. This will be accomplished by sheeting or sand bagging. However, the need for such precaution and the method to be employed can be ascertained from the highway department during the design phase of the project.

9.07 DEAD RIVER

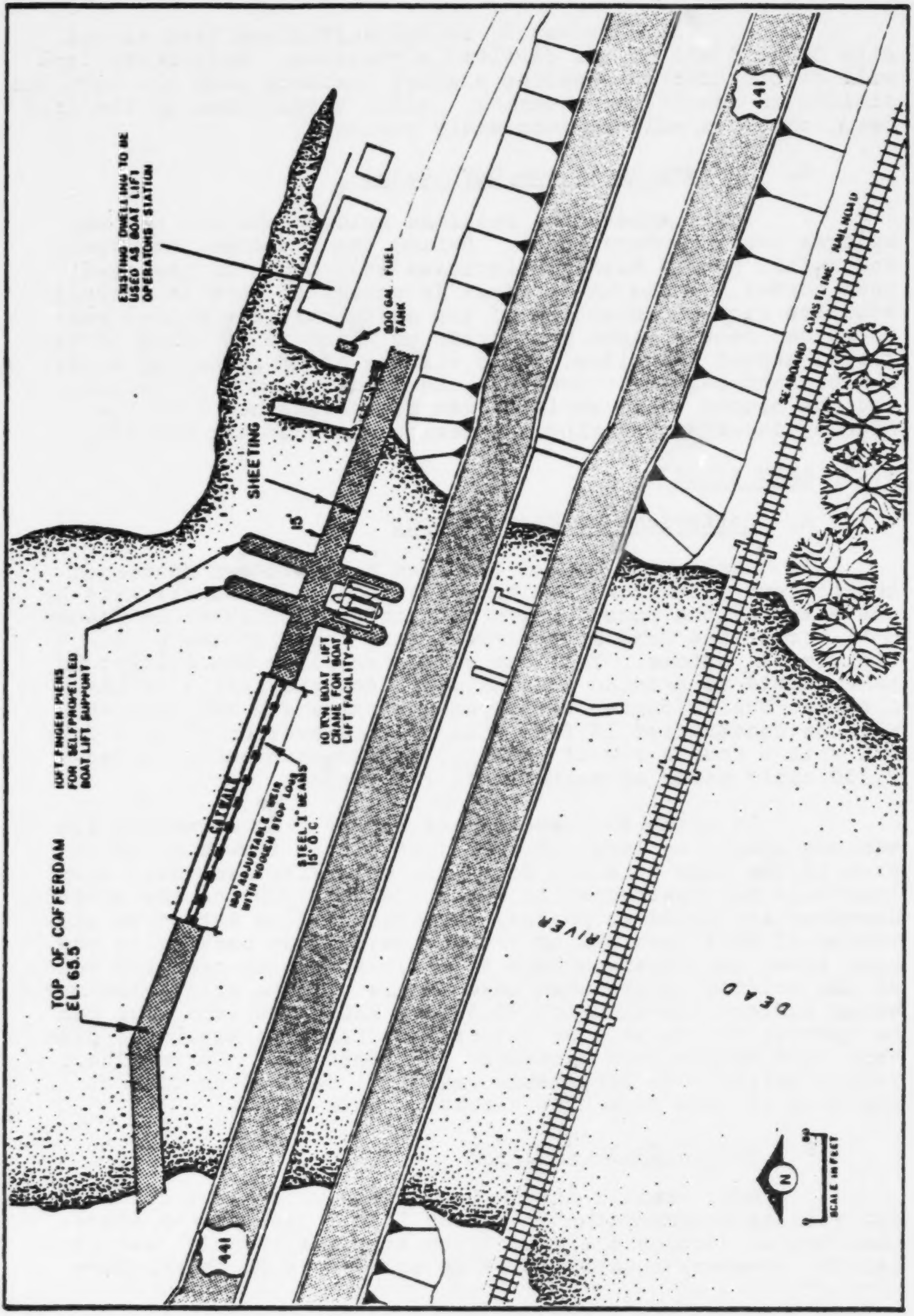
A. Cofferdam and Flow Control

During the pumped drawdown and holddown phases of the project, backflow from Lake Eustis to Lake Harris will be prevented by the construction of a cofferdam (shown in Figure 9-8) across the Dead River immediately north of the U. S. Highway 441 bridge. This dam will also allow the filling of Lake Harris to provide storage water for the refill of Lake Apopka. The cofferdam will span approximately 530 feet and will be constructed 15 feet wide to an elevation of 65.6 feet MSL with a double row of sheeting filled with an estimated 2,500 cubic yards of suitable fill material.

In order to prevent Lake Harris from exceeding its maximum operating level of 63.5 feet MSL, a flow control device in the form of a 150 foot long weir with removable stop logs will be constructed in the cofferdam. During the pumped drawdown and holddown phases, the weir will be set at an elevation of 65.5 feet MSL to prevent water from backing up the Dead River and entering Lake Harris, especially near the end of the holddown phase when Lake Eustis will be at its maximum water surface elevation of 63.5 feet MSL. The stop logs can be removed in the weir as required during this period to prevent Lake Harris from exceeding 63.5 feet MSL. During the refill period, the adjustable weir will be used to control the rate of flow from Lake Harris to Lake Eustis.

B. Boat Lifting Facility

Boat traffic in the Dead River which must cross the dam will be accommodated by a boat lift. Most of the boats that travel through the Dead River are less than 20 feet in length, however, houseboats of up to 40 feet in length have


EXISTING DWELLING TO BE USED AS BOAT LIFT OPERATIONS STATION
500 GAL. FUEL TANK
SHEETING
15'
10FT FINGER PIERS FOR SELF-PROPELLED BOAT LIFT SUPPORT
10 TON BOAT LIFT CRANE FOR BOAT LIFT FACILITY
CATWALK
180' ADJUSTABLE WEIR WITH WOODEN STOP LOGS
STEEL "I" BEAMS 15' O.C.
TOP OF COFFERDAM EL. 65.5'
441
441
SEABOARD COASTLINE RAILROAD
DEAD RIVER
N
SCALE IN FEET

Dead River dam and boat lift facility.

FIGURE 9-8

been observed.

A 10-ton capacity Travel Lift crane which is self-propelled and supported on four running wheels that would be supported on finger piers built integrally with the cofferdam is proposed for this application. This equipment has a clear inside dimension of 14 feet and can provide a vertical lift of up to 15 feet. Two automatically controlled and energized flexible saddles or slings can be adjested to accommodate each boat at the bow and stern to provide support during lifting and transport to the other side of the dam. Boats without the typical hull configuration (such as houseboats with pontoons) would require special supporting methods. For the average 20 foot inboard-outboard motorboat using the Dead River it is estimated that about 10 minutes would be required to transport the craft from one side of the dam to the other.

Ample dock space on each side of the dam would have to be provided so that boats waiting to be lifted could be tied up in the interim. A system of docks and temporary walks will be installed to convey occupants of boats from one side of the dam to the other.

The site will require housing for the operator, radio equipment, maintenance and repair equipment. An existing building at this site which is presently unoccupied could serve this purpose satisfactorily. An existing access road from U. S. 441 to the abandoned building and the river's edge will meet the requirements of this project with the provision that a suitable turn-around facility be provided for trucks and construction equipment.

Visual water level gages will be installed on either side of the dam so that the elevation of both Lakes Harris and Eustis can be monitored.

9.08 LAKE BEAUCLAIR PUMPING STATION

A. General

The second of three refill pumping facilities will be located at the Lake Beauclair end of the Apopka-Beauclair Canal (see Figure 9-9). A cofferdam will be build across the end of the canal to support the pumping equipment and water will be lifted from the lake into the canal for conveyance to Lake Apopka. Before reaching Lake Apopka, a third refill pumping facility will be required near the Apopka-Beauclair Canal Lock and Dam. The Lock and Dam facility is described later. Details of the Lake Beauclair facility follow below.

B. Cofferdam

At the end of the holddown period, the water level in Lake Beauclair will be about 64 feet MSL. The existing ground near the end of the Apopka-Beauclair Canal is about 65 feet MSL. A cofferdam will be built across the width of the canal (about 120 feet) and tie into the existing ground along both banks. The cofferdam will be about 9 feet high (the canal bottom is about 56 feet MSL and 40 feet wide to provide sufficient space for pump equipment and vehicle access. An estimated 6,700 cubic yards of fill material will be required to build the dam.

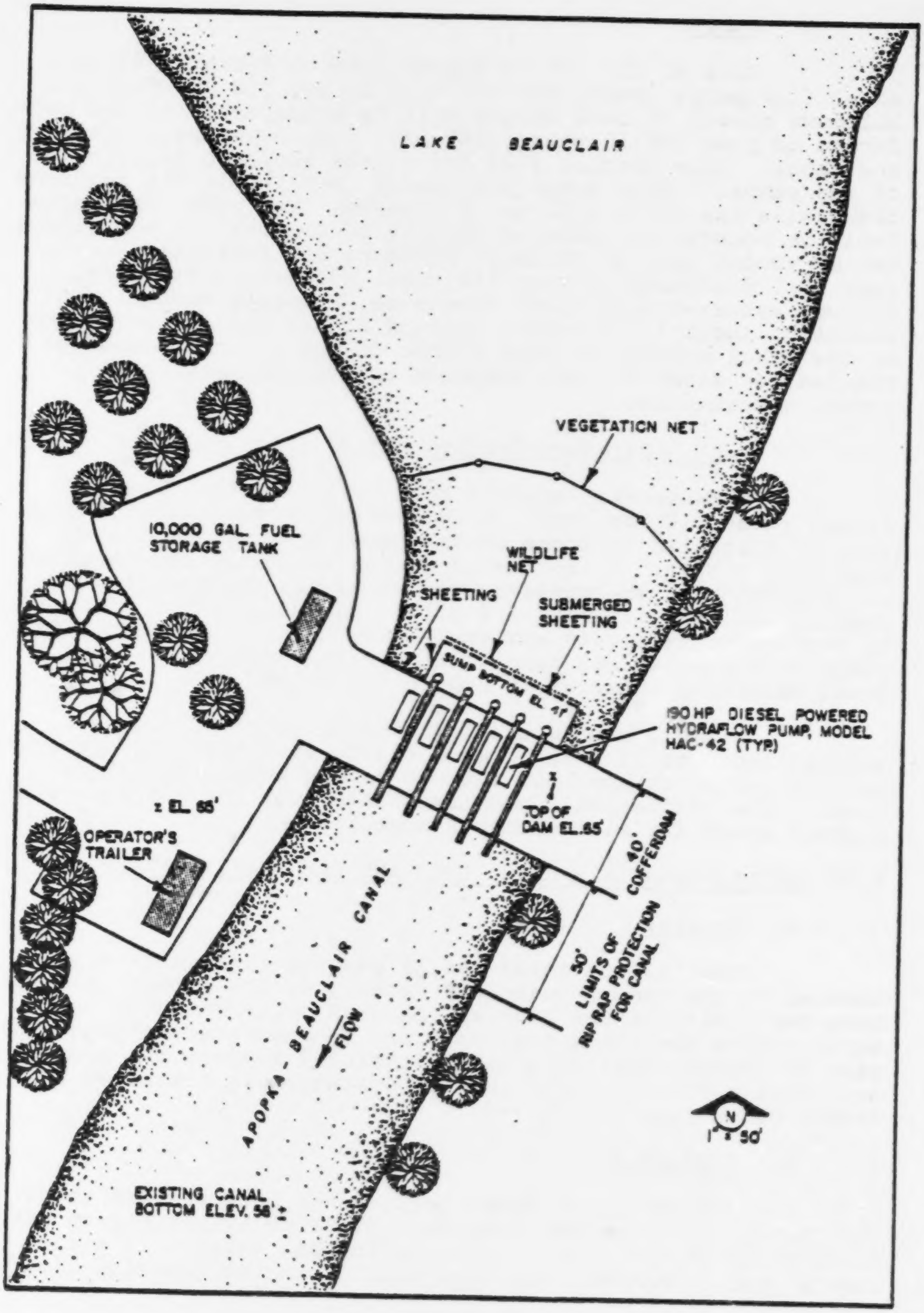
C. Access

A private farm road running from Shirley Shores Road to the citrus grove along the west side of the canal will be used for access to this site. The road must be extended a short distance from the end of the groves to the canal and upgraded to handle heavier and wider vehicles. Upgrading will probably consist of widening the road to about 20 feet, providing parking and a turn around at the site and adding sand or other suitable fill material to wet areas and low spots. Also, a few fruit trees near the site may have to be removed during construction. At the conclusion of the project, the road could either be restored to its original condition or left as modified at the owner's discretion. Compensation will also be required for fruit tree damages.

D. Sump, Weir and Protective Nets

For the pumps to function properly over the range in lake levels expected during the refill phase and the Lake Beauclair restoration phase (during which Lake Beauclair will be lowered to 53 feet MSL) an adequate water depth must be maintained over the entrance to the suction pipes. Since about 12 feet of water is necessary, a sump must be excavated to 41 feet MSL. To provide adequate space for five suction pipes, the sump must be about 17 feet wide, 55 feet long requiring about 520 cubic yards of excavation. The bottom of the sump will be lined with about 1,000 square feet of large riprap (described earlier in the drawdown facilities) to prevent scouring of bottom sediments.

Sheeting driven around the sump in preparation for the excavation will be left in place and cut off at about 52 feet MSL to allow water to enter the sump but not silt and other bottom debris. Attached to this sheeting will be supports for 800 square feet of wildlife net to keep turtles, alligators and other wildlife away from the pumps. A vegetation net will be attached to wooden posts driven into the channel bottom just upstream of the intake sump. Approximately 200 square feet of vegetation net will be required to keep floating hyacinths and other plants away from the pump intakes. The wildlife net will extend to the bottom of the canal while the vegetation net would only reach about 2 feet below the water surface.


LAKE BEAUCLAIR
VEGETATION NET
10,000 GAL. FUEL STORAGE TANK
WILDLIFE NET
SHEETING
SUBMERGED SHEETING
SUMP BOTTOM EL. 41'
190 HP DIESEL POWERED HYDRAFLOW PUMP, MODEL HAC-42 (TYP.)
± EL. 65'
TOP OF DAM EL. 65'
40' COFFERDAM
OPERATOR'S TRAILER
30' LIMITS OF RIP RAP PROTECTION FOR CANAL
APOPKA - BEAUCLAIR CANAL
FLOW
N
1" = 50'
EXISTING CANAL BOTTOM ELEV. 56' ±

Lake Beauclair pumping station.

FIGURE 9-9

E. Pumps

Five of the 190 HP diesel powered Hydraflo 42-inch axial flow pumps (Model HAC-42) used during the drawdown and holddown phases on Lake Apopka will be transferred to the cofferdam to pump refill water (366 cfs) from Lake Beauclair into the canal. (See Section 9.04 for a more thorough description of the pumps.) Four pumps are needed to maintain the required flow while the fifth will be in reserve. The pumps will probably be mounted on skids which will be anchored to the cofferdam by wooden pads to minimize movement and vibration. Each pump will discharge beneath the water surface in the canal through upturned bell mouth elbows to dissipate energy. In addition, about 7,200 square feet of riprap will be installed on the canal bottom and side slopes on the discharge side of the dam for about 50 feet upstream to provide additional scouring protection.

F. Fuel, Operation Control and Noise

Because this site is relatively remote, diesel driven pumps will be used. A 10,000 gallon fuel storage tank will be installed on shore which should provide about a two week fuel supply. Noise should not be a problem for neighboring residents as the distance to the nearest permanent residential dwelling is about 1/2 mile. However, should control be necessary, temporary enclosures could be built around the pumps with accoustical panels of precast concrete or similar sound dampening material to reduce the noise.

A small mobile trailer will be provided with a two-way radio to link the pump operator with the main operation control center at the Lock and Dam on the Apopka-Beauclair Canal. The trailer will provide shelter for the operator and storage space for miscellaneous supplies.

9.09 APOPKA-BEAUCLAIR CANAL LOCK AND DAM PUMPING STATION

A. General

The last of three refill pumping facilities will be located in the Apopka-Beauclair Canal just downstream (towards Lake Beauclair) of the Lock and Dam. A cofferdam will be build across the canal just upstream of the Astatula Road overpass to control the canal water level and support the pumping equipment. This facility and its operation is described in detail below (see Figure 9-10).

B. Cofferdam

During the holddown period, the Lock and Dam gates will be opened to allow canal water to flow by gravity to Lake Beauclair. During refill the Lock and Dam gates will again remain open. However, the flow will go in the opposite direction towards Lake Apopka. The existing ground near the Lock and Dam is about 70 feet MSL. A cofferdam will be built across the width of the canal (about 100 feet) and tie into the existing ground along both banks. The cofferdam will be about 13 feet high (the canal bottom is about 57 feet MSL) and 40 feet wide to provide space for pump equipment and vehicle access. An estimated 1,200 cubic yards of fill material will be required to build the dam.

C. Access

A dirt road leading from Astatula Road to the east bank of the canal will be used for access to the site. The road will probably require some modifications as the grade may be too steep for heavier vehicles. Upgrading will probably consist of reducing the grade to Astatula Road and providing parking and a turn-around at the site.

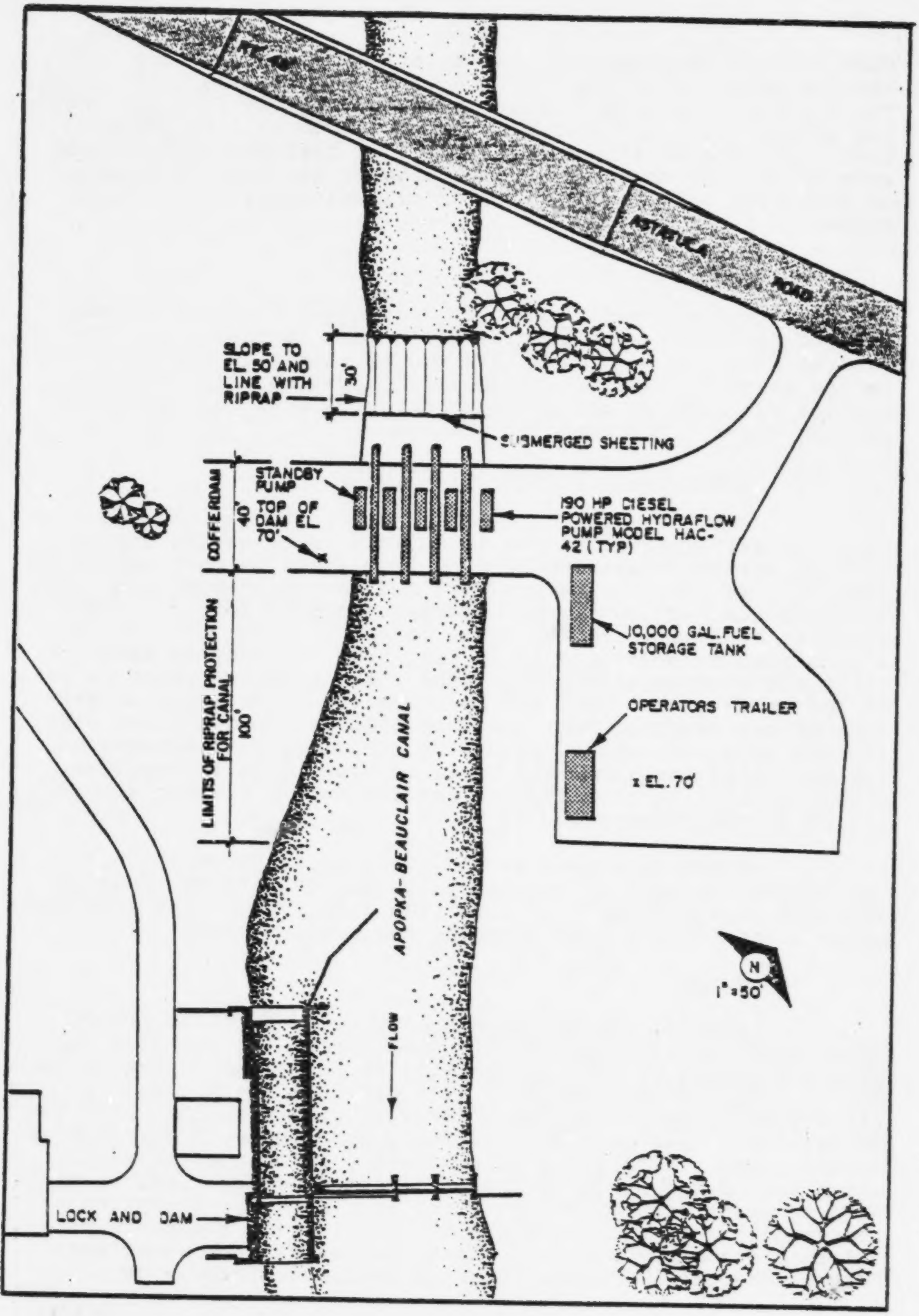
D. Sump, Weir and Protection Nets

For the pumps to function properly over the range of water levels expected in the canal (the level on the suction side of the cofferdam should drop from about 64 feet MSL to 60 feet MSL) an adequate water depth must be maintained over the mouth of the suction pipes. Because about 12 feet of submergence is necessary and the canal bottom is about 57 feet MSL, a sump must be excavated to 48 feet MSL. To provide adequate space for four suction pipes, (the fifth pipeline which is part of the reserve unit will not be installed to minimize excavation of the canal banks), the sump will be about 17 feet wide, 44 feet long and require about 250 cubic yards of excavation. The bottom of the sump will be lined with large riprap (described earlier in the drawdown facilities) to prevent scouring of bottom sidements.

Sheeting driven around the sump in preparation for the excavation will be left in place and cut off at about 58 feet MSL to allow water to enter the sump but prevent silt and other bottom debris from reaching the suction pipes.

E. Pumps

Four of the 190 HP diesel powered Hydraflo 42-inch axial flow pumps (Model HAC-42) used during the drawdown and holddown phases on Lake Apopka will be installed on the cofferdam to pump the required flow (366 cfs) to Lake Apopka. A fifth pump of equivalent capacity will remain on the cofferdam in reserve. (See Section 9.04 for a more thorough description of the pumps.) The pumps will probably be mounted on skids which will be anchored to the cofferdam by wooden pads to minimize movement and vibration. Each pump with the exception of the standby pump will have its own suction and discharge pipe (42 inch diameter) and will discharge beneath the water surface in the canal through upturned bell mouth elbows to


ASTATULA ROAD
SLOPE TO EL. 50' AND LINE WITH RIPRAP
30'
SUBMERGED SHEETING
COFFERDAM
40'
STANDBY PUMP
TOP OF DAM EL. 70'
190 HP DIESEL POWERED HYDRAFLOW PUMP MODEL HAC-42 (TYP)
10,000 GAL. FUEL STORAGE TANK
LIMITS OF RIPRAP PROTECTION FOR CANAL
100'
OPERATORS TRAILER
x EL. 70'
APOPKA-BEAUCLAIR CANAL
N
1" = 50'
FLOW
LOCK AND DAM

Apopka-Beauclair Canal Lock and Dam pumping station

FIGURE 9-10

dissipate energy. In addition, riprap will be installed on the canal bottom and side slopes for about 100 feet beyond the discharge side of the cofferdam.

F. Fuel, Operation Control and Noise

Because this site is remote, diesel pumps will be utilized. A 10,000 gallon fuel storage tank will be installed which will provide about a two week fuel supply. Noise should not be a problem for neighboring residents as the distance to the nearest permanent residential dwelling is about 1/2 mile. However, should control be necessary, temporary enclosures could be built around the pumps with accoustical panels of precast concrete or similar sound dampening material to reduce the noise.

This station will be the main control point during the refill phase. The other refill stations will be linked to this facility by radios and this station's operator will monitor the refill efforts and dictate instructions. A mobile trailer would provide shelter for the operator and storage space for miscellaneous supplies.

9.10 CITRUS IRRIGATION

A. General

The methods of fulfilling the irrigational needs of the citrus groves near Lake Apopka has been previously described in Section 6.03. The necessary facilities and the operation of those facilities are described below.

B. Facilities

Wells will be drilled prior to drawdown and used as irrigation water supply. These wells will be six inches in diameter, approximately 400 feet deep and will be cased to the top of the limestone. Pumps will be vertical turbine type, with capacity of approximately 500 gallons per minute. Pump motors will be electric or gasoline, depending on exact well location.

For groves which currently irrigate from the lake, the well pump outlet will connect to the inlet of the irrigation pump. In the case of community wells for small, abutting groves, the distance between the well and irrigation pump inlet will be traversed by aluminum pipe utilizing high pressure couplers.

In the case of groves which do not have an irrigation system, irrigation water will be applied by velocity guns mounted on a high rise traveler. These velocity guns can typically apply 500 gpm to an area 425 feet in diameter. These travelers will be connected to the supply wells by aluminum pipe and a 660 foot long, 4.5 inch diameter flexible hose.

C. Operation

Groves which are currently irrigated from the lake will utilize the wells as water supply, and can, therefore, be irrigated as desired by the manager of the grove.

In the case of groves not currently irrigated, irrigation will be dependent on the velocity gun travelers. Irrigation of these groves will be scheduled so as to conform as much as possible to the grove manager's request and minimize the highway travel time of each traveler system. Travelers will be relocated and operated by tractor or truck.

9.11 ORGANIC SOIL FARM IRRIGATION

A. General

Irrigation water needs and sources of water for the organic soil farms north and east of Lake Apopka have been previously described in Section 6.04. The following describes the necessary facilities and the operations of those facilities.

B. Facilities

Water will be transported to these farms via existing canals. Necessary enlargements, repairs and connections have been previously described in Section 6.04.

In addition, flashboard risers will be used to regulate flow into the perimeter canal. These consist of a 96-inch diameter corrugated metal pipe (30 foot long) and a 14 foot vertical riser with tracks for inserting flashboards (to control water level) as needed.

C. Operation

Operation of the flashboard risers will be left to the farmer's managers so as to allow maximum coordination with their irrigation needs and schedule.

9.12 FARMERS DIKE PROTECTION

Due to the non-uniform nature of the Farmers Dike and the apparent poor construction practices employed when the dike was built, there is some question as to its structural integrity during the drawdown, holddown and refill phases of the project. After conducting numerous field investigations and subsequent evaluations, it became apparent that:

(1) Vegetation now covers most of the existing dike;

that this vegetation will probably not expire during lake drawdown; and that this material will tend to reduce loss of dike due to wind action.

(2) If the water surface on both sides of the dike is maintained fairly close to normal levels, that the dike will probably not be significantly impacted.

(3) The dike is so non-uniform, that extensive geotechnical testing designed to predict dike conditions would not significantly improve the estimate.

(4) An acceptable approach would be to constantly, during the restoration project, monitor the condition of the dike and have equipment and labor forces available to repair any section of the dike that fails.

The plan devised to deliver irrigation water to the farms calls for the repair of the Willow Dike and the use of the channel between the Willow Dike and the Farmers Dike. This plan will constantly maintain water against the Farmers Dike and prevent drying and possible damage. The portion of the dike west of the North-South McDonald Canal will not receive the benefit of the canal supplying water to the farmers, however, the dike is somewhat protected by heavy swamp-like growth lakeward of the dike.

The dike will be constantly patrolled during the restoration project, and any section that fails will be immediately repaired. A special crew will be available to perform this task.

9.13 LAKE BEAUCLAIR RESTORATION FACILITIES

A. Lake Beauclair Deep Hole Channel

A deep hole channel will be necessary to facilitate the drawdown and holddown of Lake Beauclair. The channel will be approximately 3,000 feet long, 210 feet wide with 15:1 side slopes and average five feet deep. The channel will be dug by a floating hydraulic dredge.

B. Pumping Stations

The pumping stations located at Lake Beauclair and at the Apopka-Beauclair Canal Lock and Dam (which were used during the refill of Lake Apopka) will be used during the drawdown and holddown of Lake Beauclair. These pumping stations have been previously described in Sections 9.08 and 9.09, respectively.

C. Cofferdams

Two cofferdams are required to prohibit flow into Lake Beauclair during drawdown, holddown and refill. These will be located at the connection of Lake Beauclair with Lake Dora and with Lake Carlton.

At the Lake Dora connection, the cofferdam will span approximately 800 feet and will be constructed 15 feet wide to an elevation of 65.0 feet MSL. The cofferdam will consist of a double row of sheeting filled with approximately 1,700 cubic yards of suitable fill.

At the Lake Carlton connection, the cofferdam will span approximately 200 feet and will be constructed 15 feet wide, to an elevation of 64.0 feet MSL. The cofferdam will consist of a double row of sheeting filled with approximately 200 cubic yards of suitable fill.

D. Refill Facilities

No additional constructed facilities will be required for refill. Refill will be accomplished by removing the cofferdam and pumping station at the mouth of the Apopka-Beauclair Canal and allowing water to flow from Lake Apopka through the Apopka-Beauclair Lock and Dam and into Lake Beauclair.

REFERENCES

1. Schneider, R. F., and J. A. Little. Characterization of Bottom Sediments and Selected Nitrogen and Phosphorus Sources in Lake Apopka, Florida. United States Department of the Interior, Federal Water Pollution Control Administration, Southeast Water Laboratory, Athens, Georgia. March 1969.

SECTION 11

ESTIMATED COST OF PROJECT

11.01 General

The estimated cost of constructing the project is based upon current bid prices for similar type of work in the Florida area. Some of the major items which make up the cost of construction are discussed as follows:

(1) Civil work includes the cost of dredging, clearing, excavation, backfill, water handling, well drilling, earthwork and restoring areas to their original condition at the completion of the project.

(2) Manufactured equipment includes the purchase cost of pumps, devices and other items which are factory made and sold as equipment. Cost also includes an allowance for installing and testing the equipment with a further allowance for salvage.

(3) Miscellaneous steel includes cost for steel sheeting and other miscellaneous structural steel items and includes the cost for furnishing and installing and an allowance for salvage.

(4) Metal pipes and valves such as cast iron pipe steel pipe, corrugated metal pipe, valves and fittings includes the cost to purchase and install the item along with an allowance for salvage.

(5) Housing cost includes all material and labor costs associated with providing housing at the various facility sites where required, with an allowance for salvage.

(6) Electrical costs includes the cost to provide electrical service to equipment and housing including the cost to extend power lines where required.

(7) A contingency cost has been included to cover the costs of items which cannot be ascertained in sufficient detail in the preliminary design phase.

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11.02 TOTAL PROJECT COST

Table 11-1 presents a summary of the estimated construction cost of the project. Also shown is the estimated value of equipment that can be salvaged upon completion of the project. The total construction cost less the salvage value yields the net construction cost of $10,258,900.

Table 11-2 presents the summary of the operation and maintenance and other costs (real estate, engineering, miscellaneous technical services) associated with the project. Table 11-3 presents the estimated total project cost for three different time periods.

A. September 1978

The cost of labor and materials used to prepare these estimates were based on prevailing conditions in September 1978.

B. April 1979

If the drawdown is conducted in 1980, the project will be bid around April 1979. To account for anticipated increases in labor and materials, the total project cost (based on September 1978 dollars) was increased by five percent.

C. December 1979

If the project is delayed a year, and the drawdown occurs during calendar year 1981, the project will be bid near the end of 1979. To account for the impact of inflation the total project cost (based on September 1978 dollars) was increased by 12.5 percent.

The rapid rise in construction cost is illustrated by the Engineering News-Record Construction Cost Index, shown on Figure 11-1. The Engineering News-Record Cost Index reflects the trend of construction costs and has been widely used to update previous cost estimates to current-day figures. If, in the future, up-to-date construction cost estimates are desired, the costs in this report can be multiplied by the ratio of the Engineering News-Record Cost Index at that future time to that of the September 1978 Index, which is about 2850.

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TABLE 11-1

SUMMARY OF CONSTRUCTION COST

Item	Estimated Cost[2]
Lake Apopka Deep Hole Channel and In-Lake Sedimentation Basin	$ 3,060,000
Lake Apopka Pump Station (1)	651,500
Dora Canal South Pump Station (1)	45,900
Dora Canal Transmission Main	1,775,000
Dead River Dam and Boat Lift Facility	248,500
Dora Canal North Refill Pump Station (1)	59,700
Lake Beauclair Refill Pump Station	78,800
A-B Canal Lock and Dam Refill Pump Station (1)	176,700
Lake Beauclair Deep Hole Channel	83,700
Lake Beauclair Cofferdams at	
Lake Dora	294,000
Lake Carlton	34,300
Dike Protection and Canal Improvements	894,400
Cleanup and Restoration to Pre-Construction Conditions	
Remove all Pump Station Facilities	176,000
Remove Dead River Dam and Boat Lift Facility	56,300
Remove Dora Canal Transmission Main	490,000
Remove Dike Protection System	2,200
Remove Lake Beauclair Cofferdams	131,700
Pump Purchase and Installation	
Twenty 42-inch Diesel Powered Axial Flow Pumps @ $73,500/each	1,470,000
Seven 30-inch Electric Powered Axial Flow Pumps @ $37,000/each	259,000
Plant Piping and Installation	270,400

TABLE 11-1 (continued)
SUMMARY OF CONSTRUCTION COST

Item		Estimated Cost[2]
Citrus Irrigation		728,000
Organic Soil Farms Irrigation and Dike Protection		557,000
	TOTAL CONSTRUCTION COST	$11,543,100
Credit Items (salvage value)		
Salvage Value for Pumps @ 60% of Purchase Cost		$ 1,037,400
Salvage Value for Pipe and Fittings from Dora Canal Transmission Main @ 40% of Purchase Cost		180,000
Salvage Value for Travel Lift/Boat Lift @ 60% of Purchase Cost		15,000
Salvage Value for Deep Well Turbine Pumps and Irrigation Equipment @ 20% of Purchase Cost		51,800
	TOTAL SALVAGE VALUE	$ 1,284,200
	NET CONSTRUCTION COST	$10,258,900

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(1) Pump costs are not included in this item but are summarized in "Pump Purchase and Installation" for the whole project.
(2) Estimate based on September 1978 dollars.

TABLE 11-2

SUMMARY OF OPERATION AND MAINTENANCE AND OTHER COSTS

Item	Estimated Cost(1)
Operation and Maintenance	
Labor (24 hours per day operation)	$ 1,218,000
Diesel Fuel and Electric Power	822,600
Maintenance and Facilities	850,000
TOTAL OPERATION AND MAINTENANCE COST	$ 2,890,600
Less Salvage for Maintenance Equipment @ 40% of Purchase Cost	280,000
NET OPERATION AND MAINTENANCE COST	$ 2,610,600
Other Costs	
Real Estate (easements, etc.)	$ 32,700
Engineering Services (bidding/award & construction)	285,000
Miscellaneous Technical Services	75,000
TOTAL OTHER COSTS	$ 392,700

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(1) Estimate based on September 1978 dollars.

TABLE 11-3

TOTAL PROJECT COST

Item	Total Cost	Credit for Salvage	Net Cost
Construction	$11,543,100	$ 1,284,200	$10,258,900
Operation and Maintenance	2,890,600	280,000	2,610,600
Real Estate	32,700	-0-	32,700
Engineering	285,000	-0-	285,000
Miscellaneous Technical Services	75,000	-0-	75,000
TOTAL (Sept. 1978 Dollars)	$14,826,400	$ 1,564,200	$13,262,200
TOTAL FOR 1980 DRAWDOWN (1)	$15,567,700	$ 1,642,400	$13,925,300
TOTAL FOR 1981 DRAWDOWN (2)	$16,679,700	$ 1,759,700	$14,920,000

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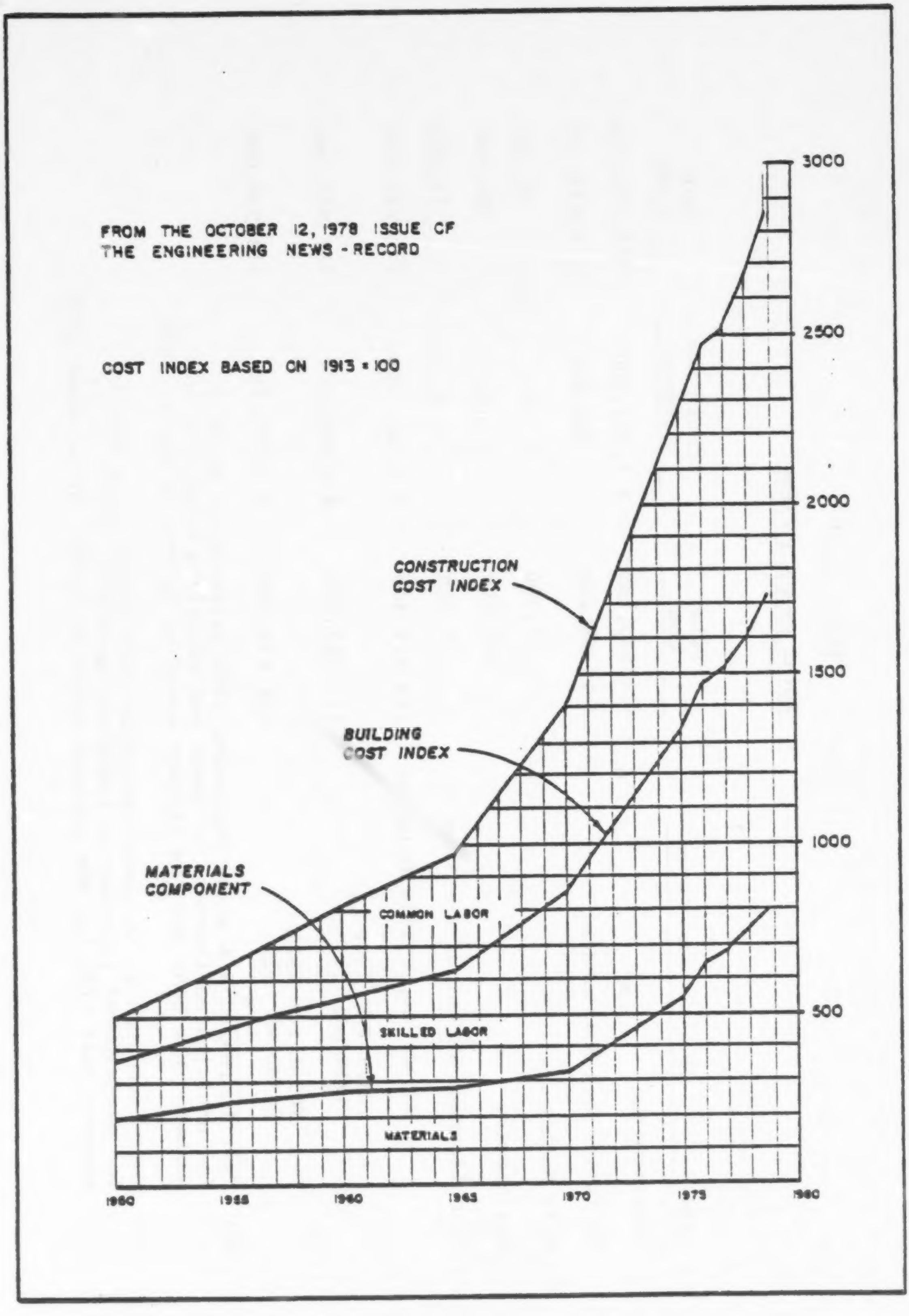
(1) Cost increased 5 % above September 1978 estimate to account for anticipated increase in labor and materials cost. It is assumed that bids for the project would be opened in April, 1979.

(2) Cost increased 12.5% above September 1978 estimate to account for anticipated increase in labor and materials cost. It is assumed that bids for the project would be opened in December 1979.



Construction Cost Index from 1950 to 1978

FIGURE 11-1

APPENDIX C

ECONOMIC TRADE-OFFS ANALYSIS

Appendix C. Economic Trade-Offs Analysis

This section outlines the economic benefits and costs that will occur if Lakes Apopka and Beauclair are restored through extreme drawdown. Benefits will be explained first, followed by a description of costs; a comparison of benefits and costs will conclude the analysis. By the very nature of this project environmental quality must be examined. Some benefits and costs, however, can not be quantified due to insufficient documentation and the difficulty of quantifying "quality."

The following economic trade-offs analysis, therefore, presents estimated benefits and costs for readily quantifiable impacts only. Intangible factors, such as improvements in aesthetic appeal or scientific knowledge, were not expressed in dollars. The final decision on this project, however, should consider all costs and benefits, be they expressed subjectively or as dollar values.

Benefits

Recreational Fishing Benefits

Although it is not in itself a precise method of evaluating Lake Apopka's recreational value, an estimate of the losses incurred by the recreational fishing industry of Lake Apopka can be obtained. This is accomplished by examining the trends of decreasing incomes and capital values of the fishing camps located around the lake. This process of reviewing foregone benefits indicates the past value of recreational fishing on Lake Apopka, thereby suggesting future potential benefits should the lake be restored to its former condition.

In 1950, the Florida Game and Fresh Water Fish Commission conducted a study of the commercial and sports fisheries of Lake Apopka. At that time, there were 13 fishing camps on the lake generating an estimated annual income of $480,000 and contributing over $1,000,000 annually to local economies (Dequine and Hall, 1961). By 1967, only nine camps remained on the lake, four of which were studied by Ledebur (1967). The average gross income of these four camps in 1965 was $11,184 compared to an average gross income of $36,923 in 1951, a decrease of 70 percent in fifteen years (Ledebur, 1967). These figures do not reflect the effects of inflation. The actual decrease in average gross incomes (allowing adjustment to 1967 dollars) was closer to 85 percent.

Unfortunately, net income data, which would be more indicative of the actual financial situation of each camp, were obtained only from two camps. One camp showed a net income of $1771 in 1965, while the other revealed net losses of $1022 in 1965 and $1233 in 1966 (Ledebur, 1967). As was mentioned in an earlier section, the number of fish camps currently on Lake Apopka has declined to four. Although these figures illustrate the trend in decreasing incomes of the fish camps, they are not a comprehensive measure of the losses in recreational benefits of Lake Apopka. A more complete measure would include the loss of restaurant and motel expenditures, travel expenses incurred in getting to and from the lake, and secondary income generated by the fish camp revenues. None of this information is available, but total losses would probably be on the order of three or four times the actual losses of income from the fish camps. This estimate, however, does give an indication of what has been lost in recreational expenditures on Lake Apopka due to the degraded condition of the lake's waters. To more accurately calculate potential recreational benefits from a restored lake, a different approach will be used.

The number of potential user-occasions for recreational fishing on a restored Lake Apopka must be estimated before benefits can be quantified. Because present participation is negligible due to the physical state of Lake Apopka, a projection cannot be made from a current survey of the lake. In addition, there are no surveys available from other lakes in the Oklawaha chain to which Apopka could be compared.

One possible source of projected recreational fishing user-occasions on Lake Apopka is Ledebur's 1967 study. Table C.1 lists Ledebur's estimates, which were calculated by applying 1965 per capita participation rates for fishing to projected populations for Lake and Orange Counties. These estimates represent baseline projections that may have been valid at the time of the study, but which have since become unreasonable. If the 1980 estimate of user-occasions is divided by the area of the lake, a usage rate of 24 fisherman-days/acre/year[3] is obtained. Although this figure is within the range of participation rates for Florida lakes, it is quite optimistic for a lake of this size. Furthermore, recreational fishing participation is not based on population alone. Numerous other factors determine actual participation patterns for all recreational activities.

Table C.1. Ledebur's 1967 Estimate of Annual Recreational Fishing User-Occasions for Lake Apopka.

	1965	1970	1975	1980
Total User-Occasions	435,145	569,426	652,440	743,349
Participation/Acre/Year	14.0	18.4	21.0	24.0

Source: Ledebur, 1967. The Economics of Water Quality Control on Lake Apopka. Florida State University, Tallahassee, Florida.

A more realistic estimate of recreational fishing on a restored Lake Apopka is based on participation rates for Lake Tohopekaliga, a 22,000-acre lake in Osceola County. Table C.2 illustrates the trend of sportfishing efforts in Lake Tohopekaliga since its restoration was completed in 1971. Although this table shows an increasing trend in participation rates, a value of 3.0 fisherman-days/acre/year will be used so that a reasonably conservative long-term estimate of fishing benefits is included in the analysis. FG&FWFC personnel feel that a participation rate of 3.0 fisherman-days/acre/year is a reasonable value for estimating fishing on a restored Lake Apopka (Holcomb and Wegener, personal communication).

Table C.2. Sportfishing Efforts on Lake Tohopekaliga, 1971-76.

Year	Participation Rate (Fisherman-days/acre/year)
1971	1.1
1972	1.2
1973	1.2
1974	2.2
1975	3.6
1976	3.6

Source: Florida Game and Fresh Water Fish Commission, 1978.

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[3] In order to simplify the benefit-cost analysis, metric equivalents may not always be given in the text.

To quantify the economic benefits of sportfishing on Lakes Apopka and Beauclair, two participation values will be used. The first is a measure of a participant's "willingness to pay" for the use of a facility. Using the Water Resources Council's unit-day value approach, the average value of a recreational fishing experience is estimated to be $1.50/fisherman-day.

In addition to this willingness to pay for the use of a facility, there are transportation expenses involved in getting to the lake, motel and restaurant expenditures, and purchases of equipment and bait. These "gross expenditures" make up the second participation value. If benefits are to be analyzed from a national perspective, these expenditures would not be added to the unit-day value, because they would merely be transferred to Lake Apopka from another location. However, this analysis is concerned with the evaluation of the restoration of Lake Apopka, and is therefore regional in nature. From this context, the increased gross expenditures are a component of the total benefits to be derived from restoration, as they will result in increased income and employment in the Lake Apopka area. Some gross expenditures will undoubtedly be transferred to Lake Apopka from other lakes in the project vicinity; however, the proportion of transferred benefits to newly created benefits is unknown.

To estimate gross expenditures related to recreational fishing, a value was obtained from the U.S. Department of Interior's 1975 National Survey of Hunting, Fishing, and Wildlife-Associated Recreation. The Department of Interior estimated the average value of gross expenditures associated with freshwater recreational fishing to be approximately $9.00/activity-day. When combined with the $1.50/activity-day unit value, we obtain a total value of $10.50 for each day of fishing. This value compares quite favorably with the figure of $10.62 derived for recreational fishing in a 1975 study of the Kissimmee River Basin (Gibbs, 1975).

The calculations for willingness to pay, gross expenditures and total benefits for recreational fishing in Lakes Apopka and Beauclair are listed in Table C.3 below.

Table C.3. Estimated Annual Recreational Fishing Benefits for Lakes Apopka and Beauclair.

Willingness to Pay = \$1.50/fisherman-day
Gross Expenditures = \$9.00/fisherman-day
Average Participation Rate = 3.0 fisherman-days/acre/year
Lake Apopka = 31,000 acres
Lake Beauclair = 1,117 acres

Total 32,117 acres

Willingness to Pay

32,117 acres X 3.0 fisherman-days/acre/year
X \$1.50/fisherman-day = \$144,527

Gross Expenditures

32,117 acres X 3.0 fisherman-days/acre/year
X \$9.00/fisherman-day = 867,159

Total \$1,011,686

Thus, one estimate of annual recreational fishing benefits is approximately \$1 million.

A much more optimistic estimate of recreational fishing benefits is derived from an expenditures per hour basis. The FG&FWFC estimates expenditures from recreational fishermen to be \$3.46 per hour. This value was derived by Game and Fish personnel for all types of fishermen on Lake Jackson in Leon County (Wegener and Williams, 1977). Should Lakes Apopka and Beauclair in their restored state generate similar hourly expenditures and should the participation rate for these lakes be similar to Lake Tohopekaliga in its restored state (i.e., 3.0 fisherman-days/acre/year), gross annual recreational fishing benefits of the restoration could be \$2,000,247 (32,117 acres X 3.0 fisherman-days/acre/year X 6 hours/fisherman-day X \$3.46/hour). Hence, annual recreational fishing benefits are projected to range between \$1.0 and \$2.0 million, with the lower figure being a more conservative estimate.

The 1970 Lake Tohopekaliga drawdown restoration produced similar economic benefits from recreational fishing activities. The standing crop estimate for all species of fish in the littoral zone of this lake in 1970 was approximately 191 lb/acre. This value peaked at 455 lb/acre two years after refill and then decreased to 315 lb/acre in 1977 (Wegener and Williams, 1977). Because of this tremendous increase in fish population, fishing pressure on the lake increased by 78 percent from 1970 to 1975. Over this same time period, bass fishing increased by nearly 400 percent (FG&FWFC, 1978). Standing crops of fish have since decreased in the lake primarily because of the continued stabilization of water levels and discharge of sewage wastes to the lake system.

Monetary expenditures by largemouth bass fishermen alone increased from $160,000 in 1970 to an average of $750,000 in both 1975 and 1976. More significantly, these bass fishermen accounted for only 54 percent of the angling pressure on Lake Tohopekaliga in 1975 (Wegener and Williams, 1978). Even though fish populations have decreased somewhat in recent years, the lake still experiences heavy recreational fishing activity. At its present rate of use, "the lake fishery generates annually approximately $1.5 million worth of revenue to the areas' economy" (FG&FWFC, 1978). Recreational fishing, therefore, can account for substantial economic benefits to lakeside areas following improvements in water quality and game fish populations.

Recreational fishing benefits for Lake Apopka will depend on numerous additional factors. For example, an extensive littoral zone is required before long-term increases in standing crops of game fish will occur. Lake Tohopekaliga's pre-existing littoral zone increased substantially following refill; however, Lake Apopka's virtually non-existant littoral zone may well require a significantly longer period to establish itself. Further recreational fishing benefits will depend upon the success of the restoration project in improving water quality and the ability of fish camps and support facilities to re-establish themselves following the restoration. In addition, fluctuating lake levels and enforcement of nutrient abatement programs are necessary if the Lake Apopka area is to experience long-term recreational fishing benefits.

Commercial Fishing Benefits

As previously discussed in Section 5, under Socioeconomic Impacts, commercial fishing on Lakes Apopka and Beauclair will be disrupted during the restoration project. Since commercial fishermen are basically transitory and do not depend on any one lake for their income, the drawdown should not significantly impact commercial fishing in the Oklawaha Basin. Fishing businesses established on Lake Apopka will definitely be affected, but fishermen in general may experience a financial gain from the project if current restrictions are altered during drawdown to encourage maximum harvesting of fish. Catfish would be the most valuable catch per pound, although gizzard shad could yield greater total gross revenues. Fishermen could concentrate on Lake Apopka during drawdown and harvest large numbers of fish with relative ease. Following drawdown the fishermen could then work the other lakes as per their normal schedule.

To make commercial harvesting of shad feasible, the use of gill or haul seine nets is necessary. Haul seine nets, however, which must drag the bottom to be effective, could conflict with the use of catfish traps and trotlines. These conflicts could then lead to disagreements among commercial fishermen, thereby reducing the effective removal of fish. Three possibilities will be discussed, therefore, in this section of the analysis: (1) only shad will be harvested, (2) only catfish will be harvested, and (3) a coordinated effort will permit removal of both species.

According to the FG&FWFC (1976), the 1976 estimated standing crop of gizzard shad in Lake Apopka was 503,040 kg (1,109,203 lbs). This type of shad sells for crab bait at \$.18-.22/kg (\$.08-.10/lb) (Metts, commercial fisherman, personal communication). Assuming 75 percent of the standing crop is harvested as the lake level recedes, gross revenues of \$75,456 could be realized (503,040 kg X \$.20/kg X .75 = \$75,456). These revenue figures also assume that all of the harvested shad could be sold. Other factors such as supply and demand effects on the market, other sources of crab bait, harvesting success, and fluctuations in the standing crop could alter the expected revenues accordingly. In addition, these estimated revenues would accrue from gizzard shad removal only. If removal of other rough fish proves profitable, the expected revenues will rise even further.

Since Lake Apopka is not presently fished for shad, there will be no long-term gain or loss to commercial shad fishing as a result of the restoration. The drawdown-related shad harvest would simply be a one-time beneficial impact of the project. Substantial shad populations may remain following restoration, but gill nets will still be prohibited on the lake because their use adversely impacts the sports fish populations. Therefore, long-term benefits to shad fishermen will not accrue unless the FG&FWFC changes their ruling on the use of gill nets in Lake Apopka.

Catfish are currently harvested from Lake Apopka, and are sold to local distributors for approximately $1.06/kg ($.48/lb) (Metts, personal communication). Since catfish are readily marketable and commercial fishing for catfish is well-established in the area, harvesting of these fish could increase dramatically during drawdown. FG&FWFC (1976) estimates place the standing crop of catfish in Lake Apopka at 53,139 kg (117,172 lbs). Assuming only harvesting of catfish is permitted (i.e., haul seines are prohibited) and 75 percent of the standing crop is removed during drawdown, revenues of $42,246 could be realized (53,139 kg X $1.06/kg X .75 = $42,246).

The third possibility for the harvesting of fish during the drawdown assumes that a mutual agreement among fishermen will permit the harvesting of both types of fish. If this agreement becomes feasible, total benefits could exceed $118,000.

Both the shad and catfish standing crop estimates for Lake Apopka are based on 1975-76 samples by the Florida Game and Freshwater Fish Commission. Since then these standing crops may have fluctuated substantially. If this is the situation, then the potential revenues from fish removal during drawdown will vary accordingly. Furthermore, fish population samples for Lake Beauclair were not collected by the FG&FWFC in 1976; therefore, the above estimated revenues do not include the harvesting of fish in Lake Beauclair. Any income derived by harvesting this lake would be in addition to the above estimates.

Commercial harvesting of fish during drawdown, therefore, will yield revenues of $42,000 to $118,000 depending upon which species are removed and sold. These estimates assume that access to the remaining pools of water will be available during the drawdown. If no such access is provided and if commercial fishermen cannot find a way to reach the pools, these benefits will not occur. If an access channel is provided by the contractor, the cost of such a channel must be subtracted from gross revenues to yield net revenues.

Regardless of the success of harvesting fish during the drawdown, catfish populations in a restored Lake Apopka will increase. Wegener (FG&FWFC, personal communication) feels that upon refill the abundance of submerged terrestrial vegetation will be a suitable habitat for numerous fish-food organisms. Bacteria, protozoans, zooplankters, macroinvertebrates, and herbivorous fish will thrive on the decaying vegetation, thereby providing a considerable food source for both game and forage fish. Furthermore, such vegetation, until it decomposes or is replaced, can serve as spawning substrate and protective cover, while concentrating fish and invertebrate fish-food organisms.

This increase in fish-food supply will result in a highly productive fishery in Lake Apopka following drawdown. As long as the submerged vegetation supports a fish food supply, fish will reproduce rapidly in the refilled lake. However, after several years the majority of the terrestrial vegetation will have decomposed, resulting in fewer fish-food organisms and decreasing fish populations. If rooted aquatic plants become established and replace this decaying terrestrial vegetation, the fisheries will reach an equilibrium point and fish populations should establish themselves according to the restored lake ecosystem.

Catfish populations will follow this fluctuating pattern, but will be especially abundant for at least several years following drawdown.

This increase has been noted in Lake Tohopekaliga, where catfish standing crops increased in the littoral zone from 1.5 lb/acre in 1970 to 25.85 lb/acre in 1973. In the limnetic zone, catfish increased from less than 1 lb/acre to 3.21 lb/acre over the same time period (Wegener, FG&FWFC, personal comunication). These are increases of 1623 percent and 221 percent respectively.

Recent blocknet samples on Lake Carlton also show substantial increases in catfish populations since that lake's drawdown in 1977 (Bill Johnson, FG&FWFC, personal communication). Catfish, especially brown bullheads, have responded better than many other types of fish. In 1975, blocknet sampling indicated 24 lb of catfish per acre of littoral zone and 26 lb/acre of limnetic zone. By 1978, these figures had increased to 358 lb/acre littoral zone and 46 lb/acre limnetic zone (increases of 1392 percent and 77 percent respectively).

Interpolating these findings to Lake Apopka for estimating potential revenues is difficult; therefore, a range of estimates and corresponding values of catfish harvesting will be presented. In accordance with the expected fluctuation in fishery populations the following assumptions will be made: (1) no catfish will be harvested for one year following drawdown, because newly spawned fish need about one year to attain harvestable size, (2) Lake Apopka's littoral zone will be restored to some extent, and (3) 20 percent of the standing crop of catfish can be harvested each month by commercial fishermen. Further monitoring of restored lakes is necessary to support such assumptions, but at present such documentation does not exist.

If Lake Apopka's standing crop of catfish increases the same percentages as Carlton, one could expect 589.3 lb of catfish per acre of littoral zone (present value of 39.5 lb/acre plus 1392 percent increase) and only 6.4 lb per acre of limnetic zone (present value of 3.6 lb/acre plus 77 percent increase). Since this littoral zone figure is so unbelievably high, it is assumed instead that Lake Apopka will support the same standing crop per acre as a restored Lake Carlton (358.0 lb/acre littoral and 46.0 lb/acre limnetic). Thirdly, to offer a relatively conservative estimate, it is assumed that a restored Lake Apopka will support only 100 lb catfish per acre littoral zone and 25 lb per acre limnetic zone. This third assumption is not supported by any drawdown, and is meant only to yield a conservative estimate for comparison purposes.

The next assumption lies in estimating the increase in littoral zone on a restored Lake Apopka. Previous lake drawdowns have promoted the growth of littoral zones to various degrees. The difficulty, however, lies in calculating the extent of littoral zone development. Therefore, a range of 5 to 15 percent of Lake Apopka's surface area will be used as the estimated extent of restored littoral zone for this project. Again, no data are available to document such figures, but since about 75 percent of Lake Apopka was once littoral zone, this is assumed to be a conservative estimate.

Table C.4 below contains matrices estimating standing crops of catfish for littoral and limnetic zones using the various assumptions described above.

As illustrated in this matrix the highest estimated standing crop of catfish is 2.9 million pounds and the lowest is 1.0 million pounds. Although these figures are only rough approximations based on numerous assumptions, they both far exceed the 1976 standing crop of 117,000 pounds.

There is no reliable method presently available to calculate the amount of catfish commercial fishermen can harvest per month. Naturally, if a certain lake is attracting attention as a heavy producer of catfish, more fishermen will harvest that lake. Therefore, this analysis assumes that 20 percent of the standing crop of catfish can be harvested per month. With a current standing crop of 117,172 pounds, present annual revenues could exceed $135,000 (117,172 lb X $.48/lb X .20/mo X 12 mo/yr = $134,982).

If the above estimated standing crops of catfish in a restored Lake Apopka are attained, then potential annual revenues could range from $1,196,352 to $3,351,036. This presupposes that commercial fishermen could actually harvest 207,700 pounds of catfish per month (20% of 1.0 million lb) and that the market could absorb such an increase at the current price.

If Lake Apopka fishermen harvested such a quantity of catfish, it is assumed that the market would eventually be flooded, thereby lowering the market price and reducing potential benefits from the drawdown project.

Table C.4. Estimated Standing Crops (lb) of Catfish in Restored Lake Apopka.

littoral zone standing crop (lb/acre)		littoral zone in acres (% of lake)		
		1550 (5%)	3100 (10%)	4650 (15%)
Assumption 1	589.3	913,415	1,826,830	2,740,245
Assumption 2	358.0	554,900	1,109,800	1,664,700
Assumption 3	100.0	155,000	310,000	465,000

limnetic zone standing crop (lb/acre)		limnetic zone in acres (% of lake)		
		29,450 (95%)	27,900 (90%)	26,350 (85%)
Assumption 1	6.4	188,480	178,560	168,640
Assumption 2	46.0	1,354,700	1,283,400	1,212,100
Assumption 3	30.0	883,500	837,000	790,500

Combining these two matrices yields estimates of total standing crops of catfish in a restored Lake Apopka, assuming various percentages of littoral zone revegetation.

total standing crop (lbs)	littoral zone		
	5%	10%	15%
Assumption 1	1,101,895	2,005,390	2,908,885
Assumption 2	1,909,600	2,393,200	2,876,800
Assumption 3	1,038,500	1,147,000	1,255,500

Another factor to consider is the time frame over which these benefits would accrue. Since fish population sampling has not been conducted on an extended basis for restored lakes, no long-term estimate of catfish populations is possible. As previously mentioned, the restored lake must eventually reach an equilibrium point or carrying capacity at which catfish standing crops will stabilize. If this value were known, accurate estimates of long-term benefits to commercial catfishermen would be possible. Presently, only the short-term benefits can be estimated.

In summary, revenues from increases in commercial catfish harvesting could theoretically reach $1.2 to $3.4 million annually. No revenues will accrue the first year following drawdown as the catfish must multiply and attain harvestable size (9"-10"). Also, these estimated revenues are short-term only (approximately 3 years). Once the lake reaches a carrying capacity equilibrium, catfish populations will adjust to the new ecosystem and will not be nearly as abundant as immediate post-drawdown populations. Long-term catfish populations and revenues cannot be estimated at this time due to a lack of monitoring data.

Other Recreation-Oriented Benefits

In addition to the fishing benefits discussed above, the restoration of Lakes Apopka and Beauclair will generate other recreation-oriented benefits. Lake Apopka currently has a poor public image. Most tourists and Florida residents view the lake as a polluted water body that is unavailable for meaningful recreational experiences. Therefore, recreational usage of Lake Apopka is almost non-existant. Some fishing and boating occur on the lake, but these activities are so scarce as to be negligible. Although Lake Beauclair's public image is not as tarnished, it too offers few recreational opportunities. A successful, well-publicized restoration project, however, should alter the public's image of Lake Apopka and significantly increase visitation and utilization of the two lakes.

Activities which could experience enhanced participation as a result of the restoration project include boating, picnicking, sailing, water skiing and scenic appreciation. Swimming, wading, and diving may also be enhanced after the restoration, although the presence of alligators and the lack of adequate beaches will minimize this increase. Table C.5 summarizes the anticipated increase in demand for outdoor recreational activities by 1990 for Regional Planning District VI, the district in which Lakes Apopka and Beauclair lie.

It should be understood that this increased demand is for the entire seven county region, and not solely for Lake Apopka. Also much of the increase in demand could be assimilated by existing facilities. This table does show, however, that the demand for outdoor recreational activities in District VI is expected to increase significantly in the next ten years, and Lakes Apopka and Beauclair, if restored, could absorb some of the demand. The restored lakes would also reduce crowds at other outdoor recreation sites in Central Florida, thereby increasing the value of the recreational experience to the remaining users of those sites.

Table C.5. Current and Predicted Outdoor Recreational Participation in Regional Planning District VI (in millions of user-occasions).

	Present Usage (1975)	Future Usage (1990)	Net Increased Usage (1975-1990)
Freshwater power boating	2.6	3.7	1.1
Picnicking	5.0	6.8	1.8
Camping			
recreation vehicles/trailers	2.8	3.7	0.9
tents	1.3	1.8	0.5
Water skiing	0.8	1.2	0.4
Freshwater sailing	0.5	0.7	0.2
Canoeing	0.7	0.9	0.2
Nature observation and study	1.1	1.5	0.4
Total	14.8	20.3	5.5

Source: Florida Department of Natural Resources, 1976. Outdoor Recreation in Florida.

Due to inadequate data and uncertainties, no estimate of the magnitude of other recreational benefits is included in this analysis. The increase in recreational activities around and on the restored lakes, however, will lead to increased business at lodges and fish camps, and at other developments associated with recreation and tourism.

Property Value Benefits

The restoration of Lakes Apopka and Beauclair should enhance the land values of lakeside residential properties. This increase is expected because improved water quality enhances the potential use of property, thereby increasing perceived benefits to both buyers and sellers. Also, the market value of lakefront property is more responsive to perceived rather than objective water quality parameters. Odor, floating debris, water clarity, recreation potential and wildlife support capacity are most important in the forming of human perceptions of a lake's utility (Supplement 13, Chapter 17-3, Florida Administrative Code). Property value is merely a measure of the buyer's "willingness to pay" and reflects his expected utilization of the lakeshore property.

In an attempt to quantify this expected increase in property values, the DER compared past and present property values around several lakes in the Oklawaha chain. By analyzing past trends in property values and comparing these increments to changes in the water quality of adjacent lakes, DER hoped to identify a correlation between these two factors. Once this relationship had been ascertained, the correct increments could be related to expected water quality in restored Lakes Apopka and Beauclair. Unfortunately, numerous interpolations and assumptions, and a general lack of reliable data prevented the investigation from reaching any significant quantifiable relationship.

Aside from these difficulties, the restoration project is certainly expected to increase property values near Lake Apopka. Dornbusch and Barrager in their 1973 study on water pollution and property values found that single-family waterfront residences can increase in value by 3 to 25 percent as a result of pollution abatement programs. The following quotation further summarizes their findings:

> "If people consider a stream or lake to be an amenity, they will be willing to pay more to live near it....However, if the water is badly polluted, it ceases to represent an amenity to nearby property owners, and consequently the value of properties near the water will decrease. As the water quality subsequently improves, nearby property values will increase accordingly to reflect the water body's value as an amenity."

Downstream property values may also increase as water quality in these lakes improves through the continual flushing effect of Lake

Apopka. In any case, in addition to enhancing the economic well-being of property owners, an increase in land values would subsequently lead to increased tax revenues for Orange and Lake Counties.

Scientific Benefits

Another intangible benefit of the restoration project relates to advances in scientific knowledge. Regardless of the project's success, understanding of the physical and socioeconomic impacts of drastic drawdown as a lake restoration technique will increase dramatically.

From an applied scientific perspective, a great deal of knowledge could be attained concerning (1) the capability of ecosystems to recover from stress, (2) the reversibility of eutrophication, and (3) impacts from cultural developments adjacent to lakes.

From a purely scientific perspective, potential advancements in knowledge include:

1. the importance of internal loading of phosphorus from bottom sediments;
2. competitive interactions between phytoplankton and rooted aquatic vegetation;
3. impacts of consolidated bottom sediments on the re-establishment of benthic vegetation;
4. the recovery of benthic organisms following a lake drawdown;
5. succession of terrestrial organisms on an exposed, richly organic lake bottom;
6. competitive interactions between changing fish community structures;
7. competitive interactions between game fish and rough fish; and
8. consolidation of lake bottom muck deposits.

In addition, as a result of pre-drawdown studies, new knowledge concerning the effects of inland bodies of water on local meteorological conditions has already been attained. The actual drawdown should add substantially more information to this little studied area. Predrawdown studies of hydrology and limnology have also been conducted on the Oklawaha Chain of Lakes and have been the subject of several scientific

273<

papers. Additional knowledge will be attained from a socio-economic perspective. The actual effects of the drawdown on the regional economy, local businesses (such as fish camps), and land values around Lake Apopka would be of benefit to socio-economic assessments of future lake restoration projects. Changes in land use patterns and recreational activities could also be monitored for future project analyses.

Other Benefits

1. Employment. Approximately $2 million in wages will be paid to local laborers and other employees for construction and operation of the restoration project.

2. Purchase of materials. About $6 million will be spent on materials for the project. Local businesses will be used when materials transportation costs are a limiting factor. Thus, heavy materials such as concrete and stone will be purchased from local suppliers.

3. Access roads and wells. Improvements to existing roads on private land will remain at the landowners' option. Such road improvements are generally expensive and will increase the value of the land. Similarly, the addition of a deep water well for irrigation will be provided through the project. This improvement will cost the citrus growers nothing, but will provide water for future uses.

4. Aesthetic improvements. Better water quality, increased game fish populations, and a consolidated lake bottom will definitely improve the aesthetic appeal of both Lake Apopka and Lake Beauclair. Although it is impossible to calculate a monetary value for this improvement, a restored natural resource is a definite economic benefit for the region as well as the state.

5. Frost/freeze protection. Consolidation of Lake Apopka's bottom sediments will increase the volume of the lake by approximately 13 percent. This additional volume will provide better frost/freeze protection for citrus orchards along the southern perimeter of the lake.

274<

Additional benefits are discussed later in this section when benefits and costs are compared. Table C.9 contains a summary of benefits, while more detailed information is presented in preceding sections of this EIS.

Costs

Engineering Design and Construction Costs

Two alternative design plans for the Lake Apopka drawdown have been considered by DER. The first alternative, a drawdown of Lake Apopka with an on-land sedimentation basin, is prohibitively expensive. Currently, the most feasible plan is the second alternative, which calls for the drawdown of Lakes Apopka and Beauclair. The sedimentation basin for Lake Apopka would be constructed in-lake, thereby placing the cost of the project at $13,925,310. Construction work and materials constitute the major portion of the project costs; however, other costs, both quantifiable and intangible, are discussed below. Table C.6 contains the cost estimates for the alternative construction plans.

Table C.6. Cost Estimates of Drawdown Project Alternatives.

I. Lake Apopka Drawdown With On-Land Sedimentation Basin For 1980 Drawdown (bids open April, 1979)	
Project Cost	$21,602,900
Bid Cost (up 5% for inflation)	1,080,145
Total	$22,683,045
II. Lake Apopka and Lake Beauclair Drawdown With In-Lake Sedimentation Basin For 1980 Drawdown (bids open April, 1979)	
Project Cost	$13,262,200
Bid Cost (up 5% for inflation)	663,110
Total	$13,925,310

Mosquito Control Costs

As previously mentioned in the Biological Impacts section, mosquito populations around Lake Apopka will increase during the drawdown. Depending on the number of complaints received from lakeside residents, additional mosquito control may be necessary. Various authorities differ in their estimates of the severity of the mosquito problem, but in keeping with the conservative nature of this analysis, the worst case situation will be discussed.

The Orange and Lake County Mosquito Control Departments currently spray the Lake Apopka area on a weekly basis to control adult mosquito populations. Investigations to determine the optimal method of additional control shows that spraying to control adults is the only viable solution. An alternative control process involves spraying to control developing larvae in the exposed lake bed. Although this process is financially competitive with spraying for adults, vegetative growth on the lake bottom precludes the spray from reaching the larvae.

Estimating the extent of necessary additional spraying is difficult because of numerous intervening factors. Precipitation, for example, will determine how often water fills the cracks in the exposed lake bed, thereby providing a reproduction habitat. A dry year would result in fewer mosquitos, while a wet year means more mosquito larvae will survive to become adults.

Planning for worst case situations assumes that additional spraying will be necessary. This service can be performed by the County Mosquito Control Departments at $0.50/hectare ($.20/acre) (Opp, Florida Department of Health, personal communication). Since the actual amount of required spraying may vary substantially, estimates of control costs encompass a variety of situations (Table C.7).

The Lake Apopka watershed contains 1578 hectares (3899 acres) of urban landscape. Table C.7, in estimating the cost of mosquito control, illustrates the costs associated with spraying varying portions of this urban area. At no time should the entire urban area require control spraying since such a small segment actually abuts Lake Apopka. The estimates also include the possibility that affected areas may require up to three additional sprayings per week.

Table C.7. Cost Estimates for Mosquito Control.

Cost of spray: $0.50/hectare ($0.20/acre)
Total urban area: 1578 hectares (3899 acres)
Length of drawdown project: 8 months

Therefore, Cost = $0.50/ha X urban area (in hectares) X
number sprayings/week X 4 weeks/month X 8 months

	Additional Sprayings Per Week		
Portion of Urban Area	1	2	3
1/4 (395 ha)	$ 6,320	12,640	18,960
1/2 (789 ha)	12,624	25,248	37,872
3/4 (1184 ha)	18,944	37,888	56,832

The total expected costs of mosquito control for the project, therefore, range from $6320 to $56,832. Actual costs will depend on conditions during the drawdown and their effects on mosquito populations.

Mosquito control costs for the Lake Beauclair drawdown should be minimal because (1) the drawdown/holddown phase will require only 2.5 months, (2) few residential areas surround the lake, and (3) the drawdown should occur before the heavy mosquito breeding season. To account for possible spraying around Lake Beauclair, however, the maximum cost figure of Table C.7 will be included in the benefit-cost comparison.

Other Costs

Additional costs become apparent as one studies the project. These costs originate from the temporary adverse impacts of the drawdown and relate to physical, environmental damages. Certain wetland areas will be affected and some soil erosion, noise, and air pollution are unavoidable. Present recreational activities on the lakes, although negligible, will also be disrupted. Since most of these impacts are temporary and/or will be rectified upon completion of the project, no dollar value has been assigned to them. It is important, however, to include these costs when considering the feasibility of the project. Table C.9 summarizes these costs and preceding sections of this EIS explain cost impacts in greater detail.

Benefits-Cost Comparison

In this analysis no actual ratio of benefits to costs will be calculated, as this would be misleading in the evaluation of the project. Benefits have been calculated from both a conservative and optimistic standpoint to yield a range of expected values; however, many benefits and costs have not been quantified. A benefit-cost ratio would negate consideration of these important intangible benefits and costs. Furthermore, since this is a research and demonstration project, the useful life of the restored lake is unknown. Assuming a definite project life would result in a highly biased benefit-cost ratio.

A more realistic, but less definitive method will be used to evaluate the economics of the project. The majority of cost figures are quantified and require no discounting as they will occur prior to the actual restoration. Most benefits will not begin to accrue until the project is completed; therefore, quantifiable benefits will be converted to their present values at various interest rates and project lives. Table C.9, which lists all benefits and costs, will follow the discounting procedure. At this point, it is the decision-makers' role to determine if total benefits exceed costs, thereby justifying the project. This method is a more conservative decision-making tool than a specific benefit-cost ratio, because it allows for consideration of those benefits that have not been expressed in dollars. Also, the numerous unquantified benefits and costs do not permit an accurate ratio measurement.

Current quantifiable project costs include mosquito control spraying and construction costs and amount to $13,982,142 (assuming the preferred Apopka-Beauclair drawdown alternative is implemented). Any additional expenses related to the restoration project would be added to this figure to yield total costs.

Benefits to commercial fishermen could occur during drawdown; therefore, discounting of these benefits is not applicable. Assuming a 75 percent removal of both gizzard shad and catfish, revenues could amount to $118,000. To determine actual benefits, however, the cost of providing access for these fishermen would have to be subtracted from

278<

total revenues. Since no access cost estimates are available, these revenues will not be included in the benefit-cost comparison.

The only other quantified benefits of the restoration project relate to recreational fishing. These annual benefits must be converted to their present values so they can be compared to project costs. Table C.8 consists of two charts discounting future recreational fishing benefits into current values. Chart I illustrates a conservative estimate of recreational fishing benefits, while Chart II contains a much more optimistic outlook based on greater gross expenditures. The current legal discount rate for federal water resource projects is 6.875 percent; however, for sensitivity purposes, benefits have also been discounted at 5 percent, 8 percent, and 10 percent. Special circumstances surrounding a restoration of this scale may justify a different discount rate based on the preferred social rate of return.

The discount charts indicate that if only recreational fishing benefits are considered, the restoration will be hard to justify economically at any reasonable discount rate and project life. However, recreational fishing benefits are not the only economic advantages to be derived from the project. They are the only quantifiable benefits that can be discounted. Consideration also must be given to other impacts, both beneficial and adverse. Commercial fishermen, for example, should notice substantial gains in catfish harvesting due to increased standing crops in the restored lakes. Since a lack of data precludes estimated revenues from being adjusted to show potential benefits, discounting these figures would yield misleading information. Therefore, all benefits and costs must be compared and weighed outside the realm of discount charts and benefit-cost ratios. Until further quantifiable benefit-cost information becomes available, subjective judgments based on available quantifiable impacts must suffice for extensive numerical data.

Consideration should also be given to the regional multiplier effect of the drawdown benefits. The $2 million to be paid in construction wages plus the input of recreationists' dollars will stimulate the local economy and produce additional benefits. These secondary monetary benefits can be substantial for a moderately developed area such as the Oklawaha Basin.

279<

In addition to the quantified benefits and costs outlined above, numerous other impacts have been explained in this EIS. Table C.9 summarizes the benefits and costs of the Lake Apopka-Beauclair Restoration project, be they quantifiable or intangible. Deciding whether the balance between benefits and costs justifies implementation of the project can now be addressed by the proper authorities based on this input. The decision to proceed with the drawdown, however, should not be based solely on economics and probabilities of success, but should also consider the repercussion of no action and the general loss of a natural resource for today's population and tomorrow's generations.

Table C.8. Discounted Recreational Fishing Benefits of Lake Apopka-Beauclair Restoration.

I. Conservative Estimate of Recreational Fishing Benefits (Based on Average Annual Benefits of $1,011,686).

	Discount Rates			
Project Life (years)	5%	6.875%	8%	10%
5	$4,380,000	$4,160,000	$4,040,000	$3,806,000
10	7,810,000	7,150,000	6,790,000	6,216,000
15	10,500,000	9,290,000	8,660,000	7,695,000
20	12,600,000	10,820,000	9,930,000	8,613,000

II. Optimistic Estimate of Recreational Fishing Benefits (Based on Average Annual Benefits of $2,023,371).

	Discount Rates			
Project Life (years)	5%	6.875%	8%	10%
5	$8,760,000	$8,320,000	$8,080,000	$7,613,000
10	15,620,000	14,300,000	13,580,000	12,433,000
15	21,000,000	18,380,000	17,320,000	15,390,000
20	25,200,000	21,640,000	19,870,000	17,226,000

Table C.9. Summary of Major Benefits and Costs Associated with the Lake Apopka-Beauclair Restoration Project.

(Parentheses indicate section of EIS where subject is discussed in detail.)

A. Benefits

1. Increased recreational fishing--$1.0 to $2.0 million annually (Appendix C).
2. Other increased recreational opportunities on and around lakes (Socioeconomic impacts).
3. Increased commercial fishing during drawdown--$42,200 to $118,000 (Appendix C).
4. Increase in commercial harvesting of catfish following refill (Appendix C).
5. Improved water quality, and restoration and enhancement of the lake ecosystems (Water quality impacts, Biological impacts).
6. Long-term improvements in downstream water quality with associated benefits to recreation (Water quality impacts).
7. Increased value of lakeside residential property (Appendix C).
8. Advancements in scientific understanding of lake ecosystems and impacts of drawdown as restoration technique (Appendix C).
9. Local economy strengthened during project due to increased employment and sale of raw materials (Socioeconomic impacts).
10. Further, long-range economic inputs from the re-establishment of fish camps and other recreation-oriented businesses (Socioeconomic impacts).
11. Beneficial effects of fluctuating water levels on adjacent wetland vegetation (Biological impacts).
12. Increased food supply for fish-eating birds, including wood stork, bald eagle, and osprey (endangered or threatened species) (Biological impacts).
13. Elimination of periodic odor and fish kill problems presently associated with Lake Apopka (Socioeconomic impacts).
14. Aesthetic improvement of Lakes Apopka and Beauclair (Water quality impacts, Socioeconomic impacts).
15. Possible precedent set for large-scale government role in environmental restoration, leading to further restoration projects.
16. Increased frost/freeze protection for lakeside citrus orchards due to increased volume of lake after drawdown and refill (Socioeconomic impacts, Meteorological impacts).

B. Costs

1. Construction costs--$13,925,310 (Appendix B).
2. Mosquito control--$6,300 to $56,800 (Biological impacts).
3. Aesthetically unpleasing condition of lakes during drawdown (Biological impacts, Socioeconomic impacts).
4. Alligators (threatened species) will migrate to adjacent lakes; those remaining will lose one year's brood (Biological impacts).

5. Temporary water quality degradation in downstream waters due to increased nutrient levels and reduced dissolved oxygen concentrations (Water quality impacts).
6. Temporary loss of small wetland areas (Socioeconomic impacts).
7. Phytoplankton populations may increase in downstream lakes during drawdown (Water quality impacts, Biological impacts).
8. Fish kills will occur in Lakes Apopka and Beauclair; downstream fish kills are possible, but not expected (Biological impacts).
9. Construction activities will cause temporary noise and air pollution, as well as some soil erosion (Socioeconomic impacts).
10. Possible enhancement of urban encroachment on lakeside citrus lands (Socioeconomic impacts).
11. Possible loss of Department influence should project fail.
12. Possible lawsuits from various parties.
13. Potential flooding hazard should hurricane strike at beginning of refill period when downstream lakes at highest levels (Socioeconomic impacts).

APPENDIX D

FROST/FREEZE STUDY

FINAL REPORT
ON

FREEZE STUDY FOR LAKE APOPKA VICINITY,
PHASE I AND II

TO

THE FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION
AND
THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

SUBMITTED
BY

FRUIT CROPS DEPARTMENT
INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES (IFAS)
UNIVERSITY OF FLORIDA

PRINCIPAL INVESTIGATORS
JON F. BARTHOLIC AND ROBERT G. BILL, JR.
29 AUGUST 1977

Introduction

Lakes modify the air mass moving over them and subsequently moderate temperatures downwind from the water bodies. Large scale effects from lakes such as Lake Michigan have modified the agricultural operations on the western shore of Michigan. This is the only area in Michigan that large acreages of many deciduous fruits, cherries, grapes, etc., can be grown.

In Florida growers have found through experience that by planting on the southern shore of bodies of water they can obtain some moderating effect on minimum temperatures that occur during freezing conditions. The degree and extent of the area modified, however, has not been clearly demonstrated. Thus, it was not unexpected that questions should be raised concerning the moderating effect Lake Apopka has on downwind conditions, particularly on the south east sides of the lake.

To better quantitize the moderating effects and to look at possible ramifications of lowered lake level is a large undertaking. The scientific knowledge and understanding of microclimate modification relative to lakes is very limited. Thus, in our attempt to delineate the modifying effects we have used a number of approaches to allow a better understanding of this phenomenon.

In this report we have a number of sections. The first will be historic and background information relative to Lake Apopka and the vicinity immediately around that lake. The next section will include

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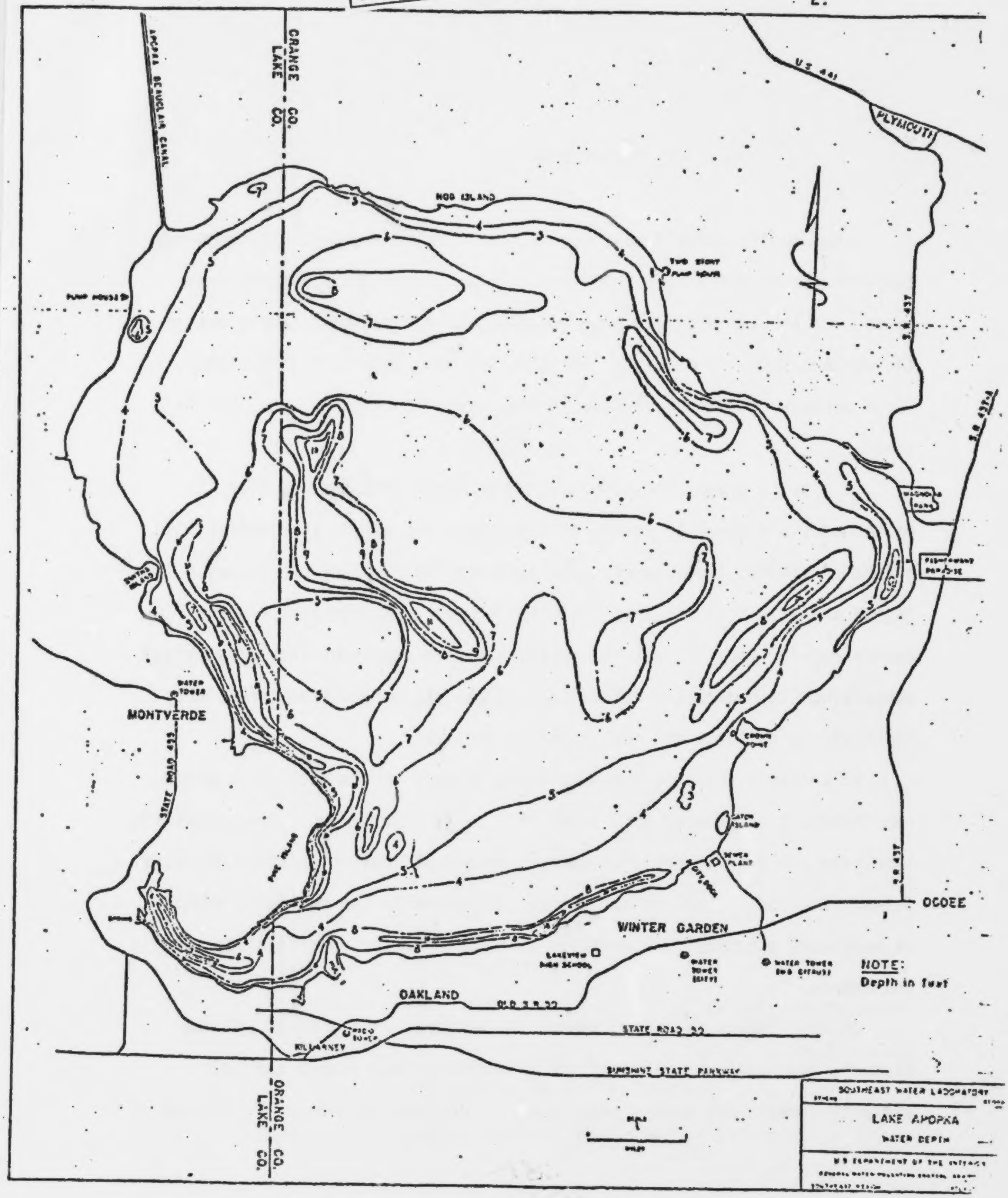
ORANGE CO.
LAKE CO.
APOPKA BEAUCLAIR CANAL
U.S. 441
PLYMOUTH
NOG ISLAND
TWO STORY PUMP HOUSE
PUMP HOUSE
S.R. 437
S.R. 437-A
MAGNOLIA PARK
MONTVERDE
WATER TOWER
STATE ROAD 455
CROWN POINT
GATOR ISLAND
SEWER PLANT
OCOEE
WINTER GARDEN
LAKEVIEW HIGH SCHOOL
WATER TOWER (CITY)
WATER TOWER (EHS CITRUS)
NOTE:
Depth in feet
OAKLAND
OLD S.R. 22
STATE ROAD 50
KILLARNEY
SUNSHINE STATE PARKWAY
SCALE
ORANGE CO.
LAKE CO.
SOUTHEAST WATER LABORATORY
LAKE APOPKA
WATER DEPTH
U.S. DEPARTMENT OF THE INTERIOR
3
4
5
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Figure 1-1 Lake Apopka, Water depth

286<

a general discussion of the approaches and procedures used to evaluate the moderating effect of Lake Apopka. Following the general discussion of approaches and procedures we have detailed reports covering each approach and procedure we used. Lastly, we will discuss the "modified lake". This section includes the special analysis of what we anticipate to be the effect if the water was at lower lake levels.

I. History and Background Information Relative to Lake Apopka

Lake Apopka is located in the central portion of the Florida peninsula. A considerable amount of citrus is grown in this area. Specifically, areas both south and east of the lake have large acreages of citrus. There is also considerable citrus west of the lake down the central ridge area of Florida. This citrus land west of the lake is on land with a fairly high elevation and good cold air drainage. The land south and east of Apopka are lower flat areas, not normally well adapted for citrus due to freeze susceptibility of these areas.

Surface and Depth Characteristics of the Lake.

In general Lake Apopka is approximately 8 miles across. Figure I-1 shows a profile of the lake and its surface area at different depths. The lake in general averages about 5.5 feet deep. One can see from Figure I-1 that much of the lake is only 4-5 feet deep but there are a few areas as deep as 14 feet. Looking at the contours of the surface area of the lake as a function of depth one sees that the surface area doesn't change much for the first two or three feet of water drop. After that point however, the surface area decreases quite rapidly with depth.

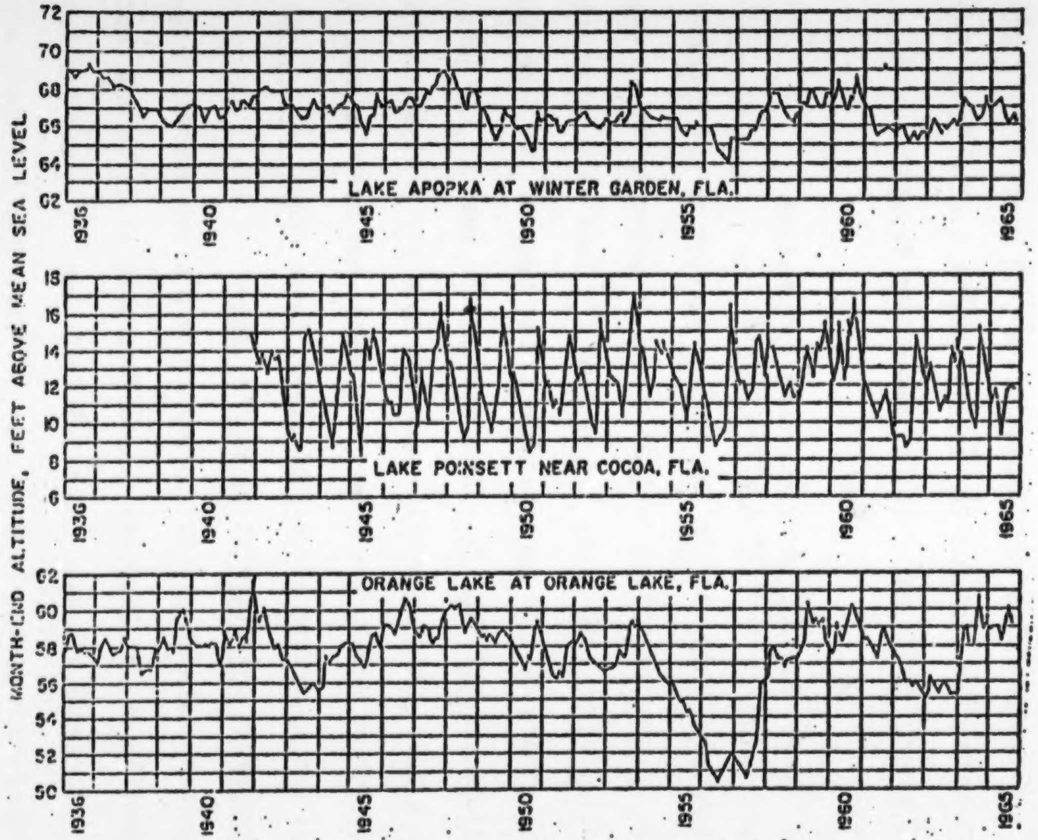

Fig. I.2 Hydrographs of month-end elevations of Lake Apopka, Lake Poinsett, and Orange Lake

Figure I-2 shows some data from the Geologic Survey showing natural variations that have occurred in the level of Lake Apopka in the past. It is immediately obvious that the lake has changed in depth considerably with time. One would assume that this is largely a function of rainfall. The main point here, however, is that the lake has varied in depth with climate conditions in the past.

Other Lake Studies.

There have been a few studies of lakes in Florida and their modifying effect in the past. Table I-1 shows a summary of some of these results. Even though they were quite variable the results do show that there was some modifying effect by Lake Santa Fe from these studies. The differences (increase in temperature on the south side of the lake over remote locations) were from 2.4 to 4.4°F on cold nights (Davis, 1963; Davis, 1958; Benson, 1960).

Table I-1.

Average Minimum Temperatures on All Nights (Davis, 1963).

	Nov.	Dec.	Jan.	Feb.	Mar.	Season
Lake Stations	48.9°	41.2°	43.1°	41.6°	53.4°	54.6°
Remote Stations	46.3	39.2	41.5	40.0	51.9	43.8
Difference	2.6	2.0	1.6	1.6	1.5	1.8

Average Minimum Temperatures on Cold Nights*

	Nov.	Dec.	Jan.	Feb.	Mar.	Season
Lake Stations	42.4°	32.0°	35.4°	36.3°	39.8°	36.4°
Remote Stations	38.0	29.6	31.7	33.9	36.1	32.9
Difference	4.4	2.4	3.7	2.4	3.7	3.5

*Cold Nights - nights with temperatures 36° or lower in peninsular Florida

II. Approaches and Procedures to be Used in This Evaluation

The first approach used is the classic approach of using thermograph data which has been acquired in the vicinity of Lake Apopka over past decades. We are fortunate since a fairly dense thermograph network is used during the winter months to characterize freeze conditions in central and southern Florida. The network is provided as a result of a cooperative agreement between the Weather Service and our Institute of Food and Agricultural Sciences. Thus, one approach is to study this period of record to first characterize the severity of freezes that might be expected and secondly to analyze the minimum temperatures and durations below critical temperatures in the vicinity of Lake Apopka. In this analysis Jim Georg, former director of the Frost Warning Service, worked up several decades of data for this study.

The second general approach is to use crop reporting service estimates. It is generally possible to obtain insurance for a citrus crop in Florida. The insurance policy rates, etc., attempt to reflect a general assessment of the freeze susceptibility of areas. Thus, the second approach discusses briefly the crop reporting services estimates of freeze susceptibility in the general vicinity of Lake Apopka

The third section uses satellite high resolution thermal data on cold nights. Temperature patterns as obtained by thermograph, although providing general information, do not provide complete thermal patterns. Complete patterns can only be assessed by studies of satellite thermal data. Section II.3. characterized general temperature patterns which persisted during one particular freeze event. The

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patterns are very intriguing and provide a valuable input in the total analysis of the cold climate in the vicinity of Lake Apopka.

The fourth section deals with a more detailed analysis of thermal patterns south of Lake Apopka. Through a cooperative program with the National Aeronautics and Space Administration (NASA), we have been able to use thermal scanners on aircraft to obtain detailed temperature patterns south of Lake Apopka.

II.1. Report on "Cold Night" Temperature Trends Around Lake Apopka.

Data used in this report were taken from the records of the Federal-State Agricultural Weather Service in Lakeland, Florida. This service has made winter temperature surveys of the Florida peninsula since 1935. A number of the temperature survey stations have been located in agricultural lands around the periphery of Lake Apopka. Data from these form the basis of this report. Circumstances often necessitate relocation of the temperature recording stations and therefore the length of record from station to station varies. Tab II.1.1 lists the stations giving their township, range and section number and other pertinent notes. Fig II.1.1 shows their approximate location with respect to Lake Apopka.

Minimum temperature data are tabulated by the Weather Service for all temperature survey stations for all "cold nights". A "cold night" is defined as one when the minimum temperature was 36F or lower at at least one station in the network. Fig II.1 2 shows the average minimum temperature for the history of the stations on all "cold nights". Generally these averages reflect a temperature climatology imposed by air flow from the northwest quadrant. However, calm nights are also a part of the data as well as nights with flow from a direction other than the northwest quadrant.

The stations in townships 21 and 22, range 27 probably warrant closest examination in any effort to discover the possible moderating effects of Lake Apopka on the temperature of surrounding areas. Many of the other stations may be influenced by numerous other lakes in the area- particularly north of Apopka. Also, station exposure, soil type, elevation, the distribution of rainfall and other more subtle influences on the daily march of temperature at a discreet point become increasingly difficult to separate from lake affect with increasing distance from the lake. Even within these boundries the effect of the soil type is probably an important factor in the difference of the averages at stations number 5, 8, and 8A (muck) and station 18 (Leon sand). This might be calculated from the theory. A first approximation may be deduced from stations number 3, 4 and 4A. The most obvious difference in the exposure of these stations is that 3 was exposed over sand while the others were over muck. But the period of record for station 3 and 4A is much shorter than for station 4. Further, the record years for 3 and 4A are different periods. Thus an approximation of 3F difference in average minimum temperature at these stations due to soil type would be crude at best. Nevertheless it is a reasonable number from theoretical considerations and does not contradict observations. If the average minimum temperature at stations 5, 8 and 8A are increased by 3F it would appear that stations 12, 18 and 21 receive some moderating influence due to Lake Apopka on "cold nights".

While Fig. II.1.2 may reveal the general "cold night" climatology of the area around Lake Apopka, it reveals nothing about the effect the lake may have on potential critically low temperatures or their duration. To gain some insight into this aspect numerous thermograms from the stations within a few miles north and south of the lake were re reviewed for freeze episodes in an attempt to show "typical" temperature tendencies. Fig II.1.3 & II.1.4 are the result of this search. These are the thermograms from stations 8 and 18 for five freeze episodes and are seemingly representative of all others reviewed in the cursory examination. The average difference in the minimum temperature for the seven cases is within 1F of the historical difference - Fig. II.1.2. It is clearly evident from Fig. II.1.3 & II.1.4 that the freeze threat is less on the south side of the lake where minima are higher and durations lower than those north of the lake. Allowing for differences in soil type, it would be reasonable to assume that at least some of the difference in freeze threat is attributable to the moderating effect of the lake. To what distance the effect extends and at what rate it decays with distance cannot be assessed accurately from the type of data used in this report; both are probably a function of the low level wind. Conceivably the effect could be zero(in the calm situation) or near zero as in the strong advection type freeze of December 12 (Fig.II.1.4)

Further insight concerning the duration of critical temperature at several locations around Lake Apopka is presented in TabII.1.2.Station 8 and 12 are of particular importance. Records from these two stations span 21 years while the others span 30 years. In the 21 year period station 8 (Zellwood) accumulated a total 267 hours at or below 26F while station 12 accumulated only 73 hours.(1) Seasonal accumulations for these two locations are plotted in Fig.II-1.5. Note that in two seasons (1959-60, 1960-61) the trend was reversed. Even though two different sources of data revealed the same thing, the data should be suspect. One possible cause of the inconsistency might be that flooding or manipulation of the water table at Zellwood had effectively moderated the micro-climate in these particular years.

Statistical probabilities for a few of the stations in Fig.II-1.1 are available - TabII.1.3.The method used to determine the probabilities is described in Climatology at Work.(2). Until the probabilities for stations 8 and 12 are determined, it may be deduced from the raw data that the probabilities for station 12 would be similar to station 2 and those for station 8 a little greater than those for station 7.

(1) Station 18 (closest to the lake) had even fewer hours below 26F but the period of record did not lend itself to comparison with station 8.

(2) Barger, G.L. (editor), 1960: Climatology at Work, U.S. Government Printing Office, Washington D.C., pp.58-59.

FIGURE II. 1.1
DATA SOURCE LOCATIONS

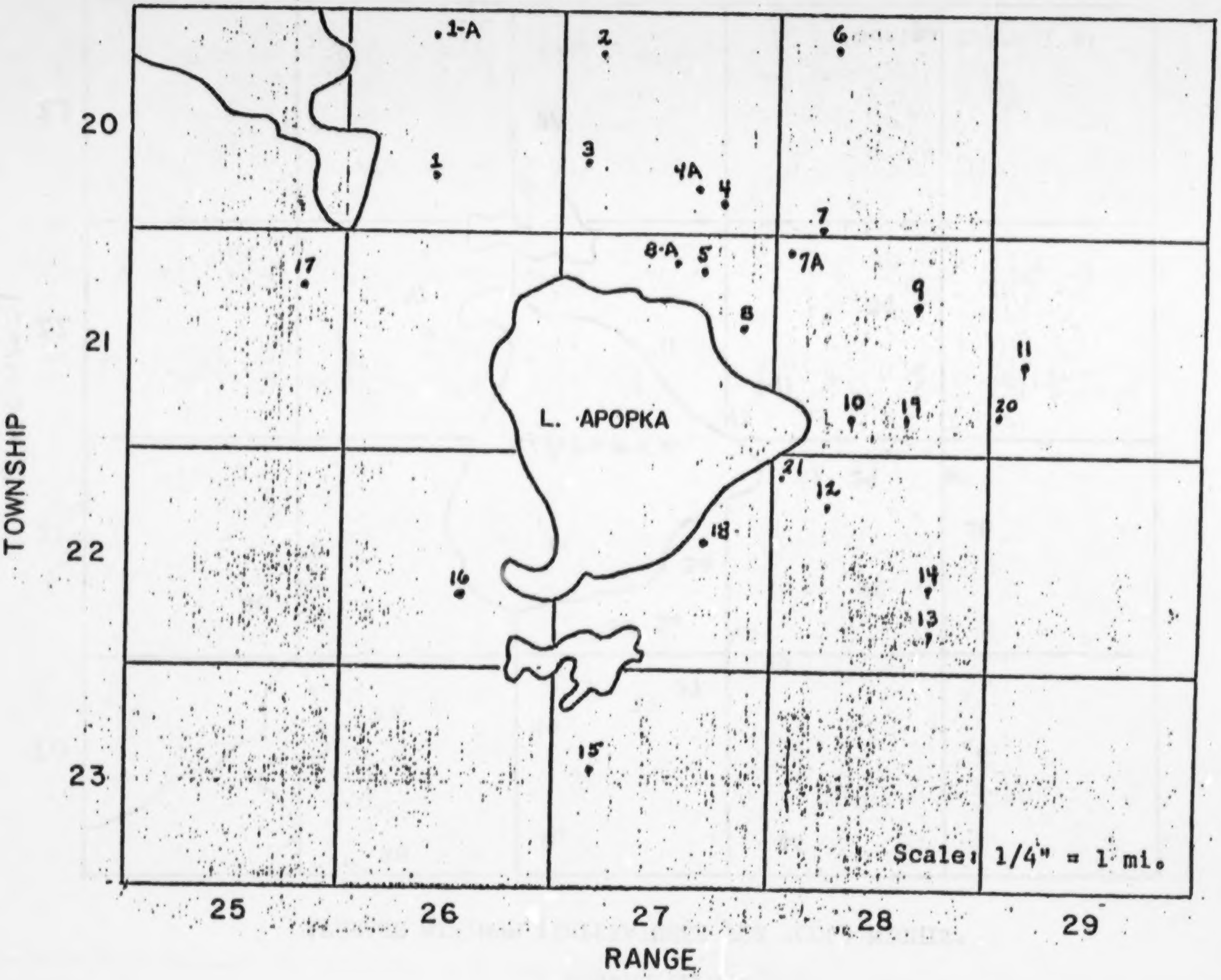

1-A
1
2
3
4A
4
6
7
7A
8-A
5
8
9
10
19
11
20
17
L. APOPKA
21
12
18
14
13
16
15
20
21
22
23
TOWNSHIP
25
26
27
28
29
RANGE
Scale: 1/4" = 1 mi.

FIGURE II. 1.2

AVERAGE MINIMUM TEMPERATURES FOR "COLD NIGHTS"

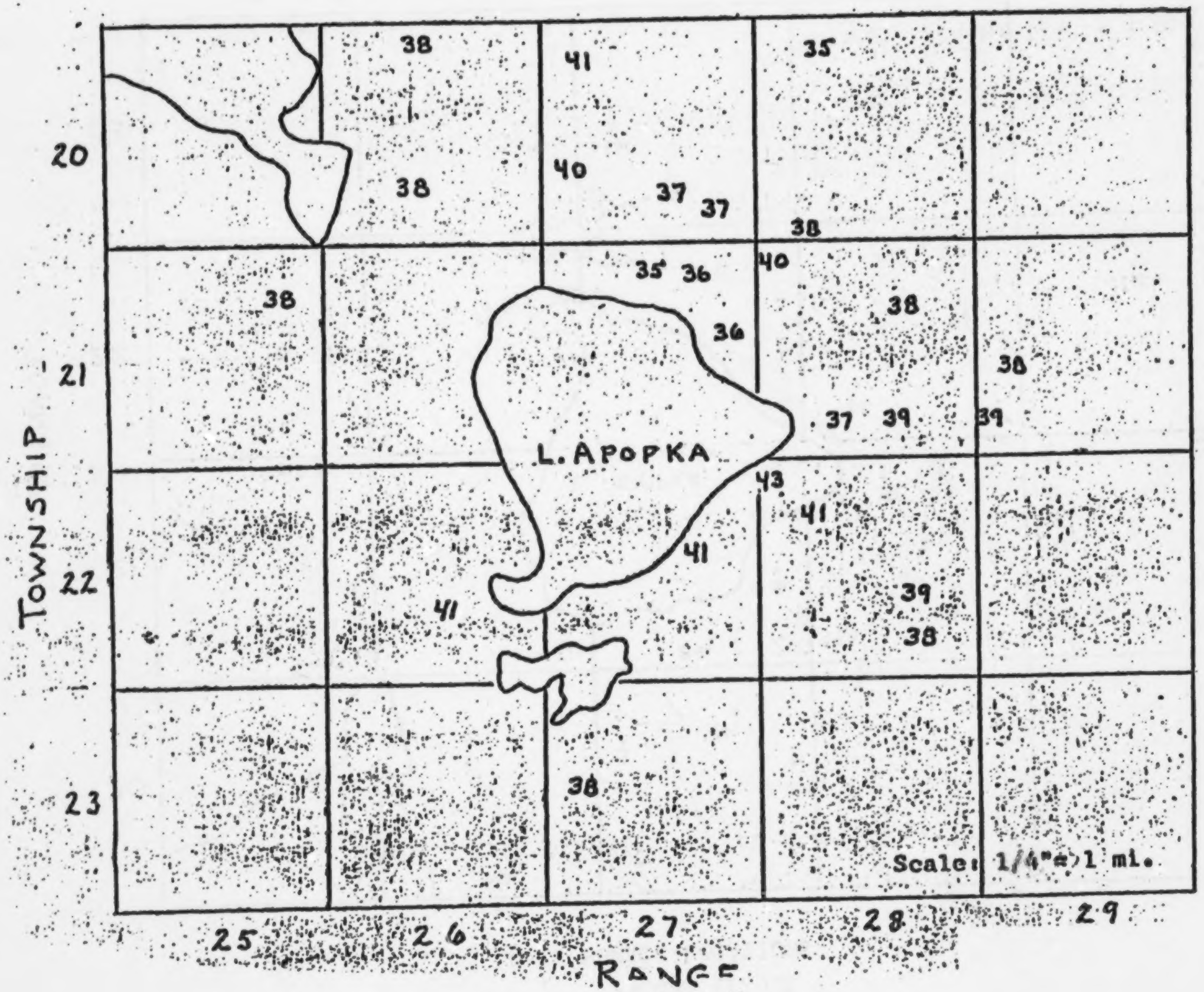

38
41
35
38
40
37
37
38
35
36
40
38
36
38
30
37
39
39
L. APOPKA
43
41
41
41
39
38
38
Scale: 1/4"=1 mi.
20
21
22
23
TOWNSHIP
25
26
27
28
29
RANGE

FIGURE II.1.3

COMPARISON OF THERMOGRAMS NORTH AND SOUTH
OF LAKE APOPKA DURING FREEZE EPISODES.

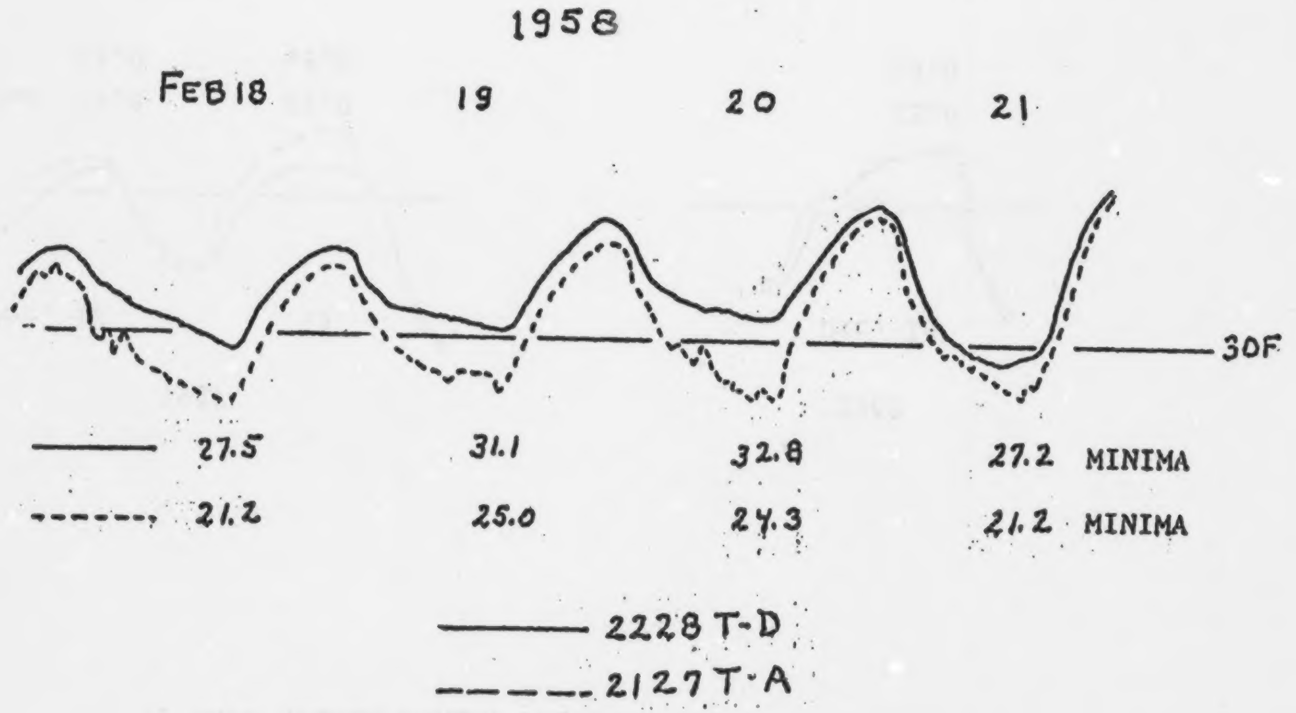


FIGURE II.1.4

COMPARISON OF THERMOGRAMS NORTH AND SOUTH
OF LAKE APOPKA DURING FREEZE EPISODES

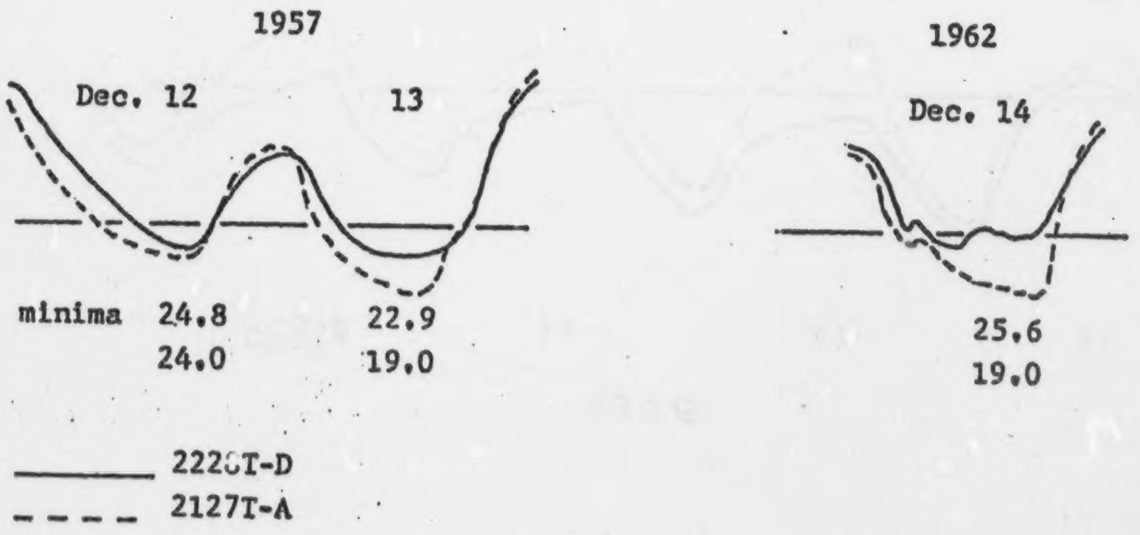


FIGURE 11-1.5

SEASONAL ACCUMULATIONS OF 26F AND LOWER

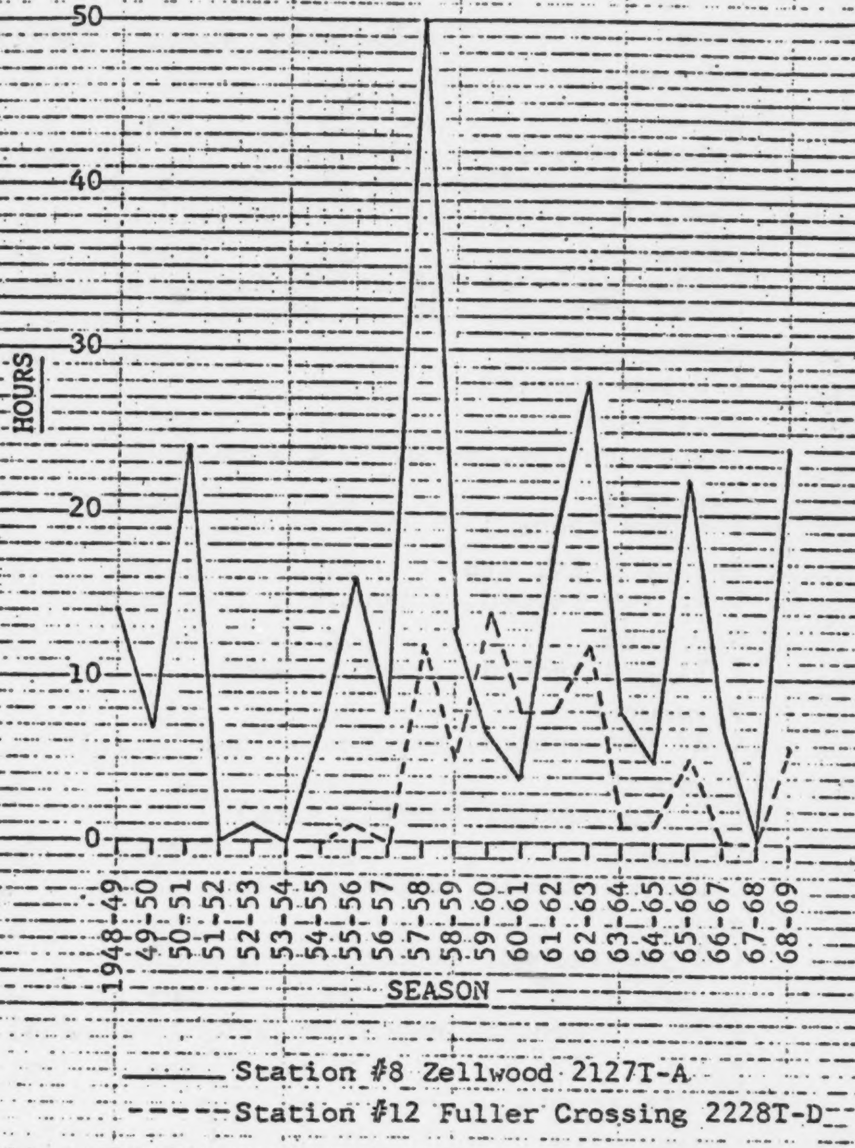


TABLE II. 1.1

KEY TO DATA POINT SOURCES SHOWN ON THE MAP , FIGURE 1

ID#	Name	Township	Range	Section
1	Astatula	20	26	4
1-A	Astatula (these were averaged together- 13 yrs record. the first influenced some by Lake Dora; the latter by Lake Harris)	20	26B	32
2	Tangerine (group of lakes N,E and W. Exposure: average low. Leon sand. 38 yrs record)	20	27A	18
3	Zellwood Sand (5 yrs record)	20	27T-C	29
4	Zellwood (exposure:low.,muck, 29 yrs record)	20	27T-B	27
4-A	Zellwood (4 yrs record)	20	27T-B	21
5	Zellwood Ex. Sta. (18 yrs record. exposure : low, muck)	21	27T-B	9
6	Sorrento (11 yrs record. frost pocket)	20	28C	6
7	Plymouth (28 yrs record. exposure: low. Norfolk sand)	20	28A	29
7-A	Plymouth (7 yrs record. Norfolk sand)	21	28	6
8	Zellwood (22 yrs record. exposure: low. muck)	21	27T-A	12
8-A	Zellwood (2 yrs record. exposure:low. muck)	21	27T	4
9	Apopka (36 yrs record. exposure: low. Leon sand)	21	28T-A	9
10	Apopka (3 yrs record)	21	28B	30
11	Forest City (33 yrs record. exposure:low. Norfolk sand)	21	29	16
12	Fuller Crossing (sometimes called Winter Garden. 18 yrs record as Fuller crossing, 11 as Winter Garden. Seemingly identical location. exposure: avg. low. Leon sand.)	22	28T-D	7

TABLE II. 1.1

KEY TO FIGURE 1 CONTINUED........

ID#	Name	Township	Range	Section
13	Orlo Vista (37 yrs record. exposure: low. Norfolk sand)	22	28B	26
14	Pickard (19 yrs record. Exposure: avg high. Norfolk sand)	22	28C	26
15	Avalon (9 yrs record. Johns Lake may influence)	23	27	18
16	Montverde (38 yrs record. exposure: high. Norfolk sand)	22	26	23
17	Howey (38 yrs record. exposure: low. Norfolk sand)	21	25	12
18	Winter Garden (19 yrs record. exposure: avg. low. Leon sand)	22	27T	13
19	Clarcona (7 yrs record. Norfolk sand)	21	28B	34
20	Clarcona (11 yrs record. Norfolk sand)	21	29C	31
21	Ocoee (very short record)	22	28	6

TABLE II. 1.2

SEASONS WITH A TOTAL OF 10 HOURS OR MORE AT OR BELOW 26F.
UNDERSCORED SEASONS HAD 20 HOURS OR MORE AT OR BELOW 26F.

Station #	Name	Year*
2	Tangerine	39,62.
4	Zellwood #1	37,39,40,42,44,46,56,57,61,62,64,65.
7	Plymouth	39,46,56,57,61,62,65.
11	Forest City	37,39,42,44,46,57,62,65.
13	Orlo Vista	37,38,39,42,44,46,50,57,58,59,61,62,64,65.
17	Howey	37,39,42,46,57,61,62,65.
**********		
8	Zellwood	48,50,55,57,58,61,62,65,68.
12	Fuller Crossing	57,59,62.

* The year is that of the beginning of the season, i.e., 37 denotes the 1937-38 season, etc..

TABLE 3

Probability (%) THE AIR TEMPERATURE WILL BE AS LOW OR LOWER THAN INDICATED TEMPERATURES AT LEAST ONCE IN ANY SEASON.

Station #	Name	16	18	20	22	24	26	28	30	32 degs
2	Tangerine		NIL	3	6	13	26	48	78	96
7	Plymouth	NIL	4	7	18	33	58	84	98*	
11	Forest City	NIL	4	9	16	34	48	85	98*	
17	Howey		NIL	8	16	31	56	82	98*	

*theoretical value

II.1 LAKE APOPKA AREA WIND STUDY (con't.)

Characteristics of the wind speed and direction in the vicinity of Lake Apopka were examined for periods of freeze episodes that had a high probability of damaging some part of the citrus tree. The period covered in this report are the years 1934 through March 1977. Although there are some scanty records of damaging freezes beyond 1934 to the middle of the last century, there are no wind records available.

The only systematic wind records available from the vicinity of Lake Apopka are those of the National Weather Service at Orlando. These form the basis for this report. The frequency of the wind observations occasionally changed over the record period. The time period used for a freeze episode in this report was 6PM EST to 7AM EST. Within this time period observations ranged from as few as three to hourly or more. Hourly observations were available for nearly eighty percent of the cases. The cases with fewer observations probably did not introduce any error, as the variability of the wind direction in the cases was seldom more than 25 degrees from the prevailing direction.

The 43.5 year record had 25 years with freezes that had a high probability of damaging citrus in the Lake Apopka area- approximately 57 percent. Tnere were 72 freeze events in those 25 years, an approximate average of three per year, see Table II.4 for a breakdown. The total hours of wind from each direction were summed for the 72 events and are presented in different forms in Fig.II 1.6 and .7 and Table II.3. Fig. 6 does not include totals less than ten hours.

Of the 72 freeze episodes:

(a) ten were of two consecutive nights duration

(b) five were of three nights duration

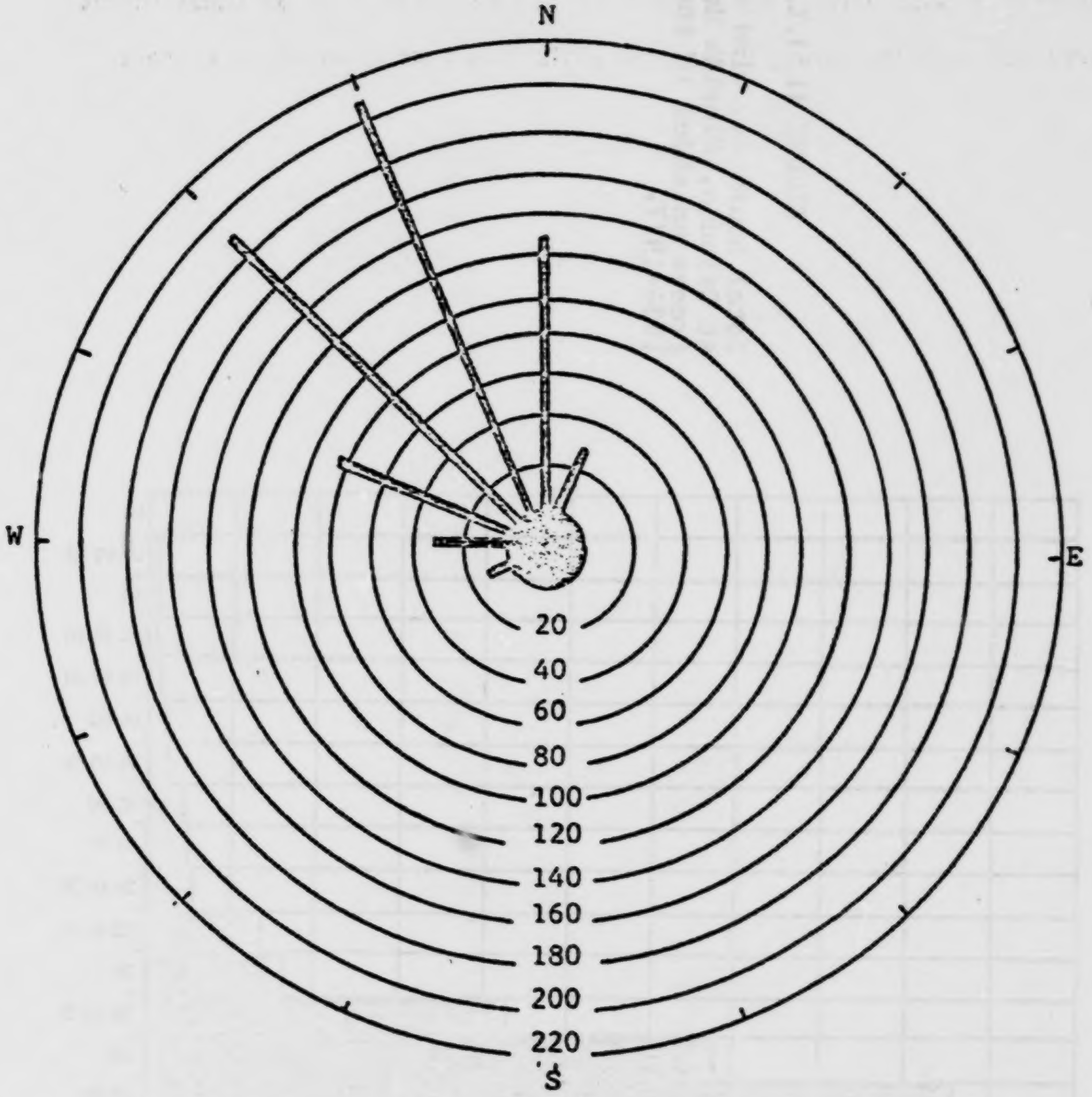
(c) two were of four nights duration

(d) and one was five consecutive nights duration.

About 67 percent of the freezes were more than one night duration.

Note: The wind velocities of Tabel II. 3 were observed in an unobstructed area and doubtless are greater than would have been observed in a grove.

FIGURE II. 1.6.



Number of hours wind was from designated direction at Orlando, Florida during 72 freeze episodes in the period 1934-1977.

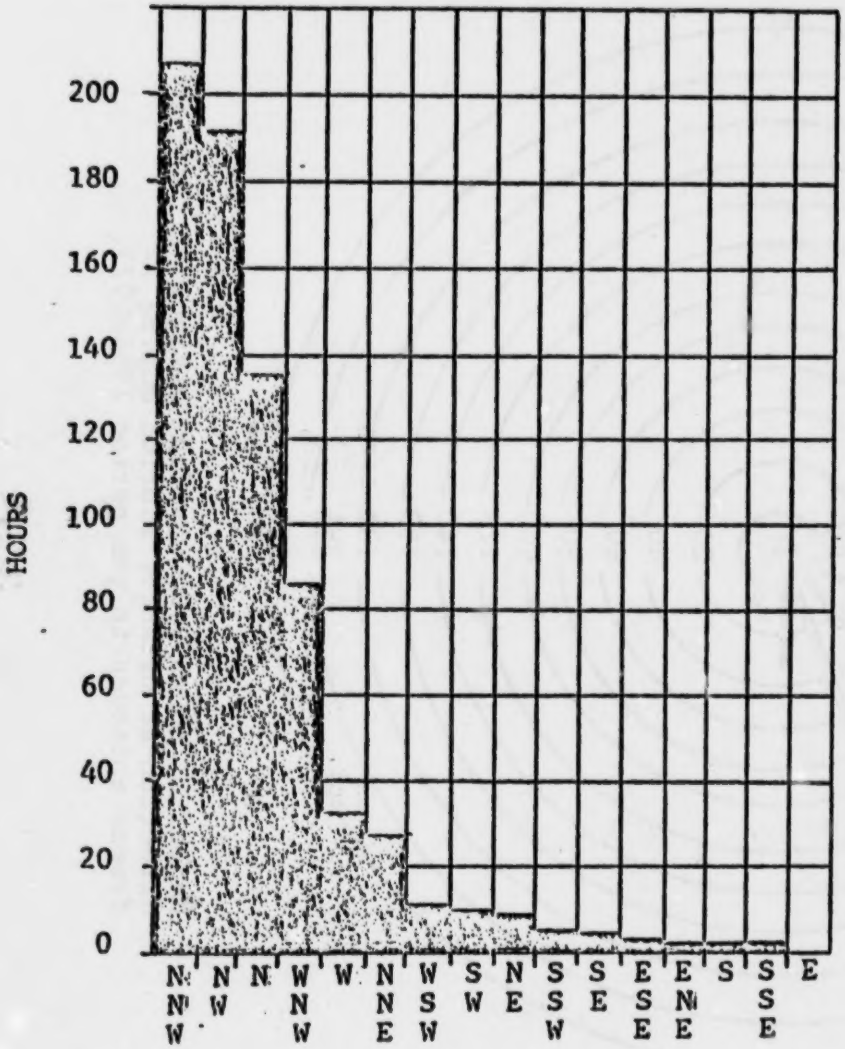


FIGURE II. 1.7.

Total hours vs. wind direction at Orlando, Florida during 72 freeze episodes in the period 1934-1977.

TABLE II. 1.3

WIND DIRECTION	TOTAL HOURS	AVERAGE VELOCITY
NNW	207	9.4 KNOTS
NW	192	8.1
N.	135	7.4
WNW	86	10.6
W	34	9.0
NNE	28	6.4
WSW	11	6.7
SW	9	6.1
NE	8	6.1
SSW	5	6.0
SE	4	3.0
ESE	3	3.0
ENE	2	7.5
S	2	4.5
SSE	2	2.5
E	0	
CALM	47	

Number of hours and average velocity the wind was from each direction at Orlando, Florida during 72 freeze episodes in the period 1934-1977.

TABLE II 1.4

Number of freeze events by years from 1934 to 1977.
Unlisted years had no freezes affecting citrus (42% of the years between 1934 and 1977.)

1934	2
1935	0
1936	0
1937	1
1938	2
1939	0
1940	6
1941	2
1942	0
1943	1
1944	0
1945	0
1946	0
1947	4
1948	2
1949	0
1950	2
1951	0
1952	0
1953	0
1954	1
1955	1
1956	3
1957	4
1958	12
1959	5
1960	6
1961	2
1962	3
1963	0
1964	2
1965	2
1966	3
1967	1
1968	0
1969	0
1970	1
1971	1
1972	0
1973	0
1974	0
1975	0
1976	0
1977	3

72 Total

II.2. Federal Crop Insurance Freeze Hazard Classifications of Areas Around Lake Apopka.

The Federal Crop Insurance Program provides the opportunity for growers to purchase insurance against crop freeze loss. These insurance premiums in areas of freeze hazards, vary as a function of many factors. The factors have been combined as a result of experience and the best judgment of those administering the Federal Crop Insurance program. They list areas of hazard varying from A through D. The A areas are those least likely to experience loss while D areas are most apt to be affected during a freeze. The premium rates per $100 of crop insurance for late oranges, for example, vary from $8.30 per acreage in the A category to $15.40 per acre for acreage found in the D category. Almost a doubling of premium rates from area A to D.

Fig. II.2.1 shows the Federal Crop Insurance classification areas in the vicinity of Lake Apopka (Clark; 1976). The A areas of least freeze hazard occupy land abutting Lake Apopka on the south and southeast side. Land classified as B areas occupies most of the additional area south and east of the lake and the A areas. However, there are a few small areas of B, but there are many large areas of C classification on the west side of the lake. Other A classifications occur south of smaller lakes and down the central ridge of Florida. The ridge is seen to the far left of this figure.

The importance the Federal Crop Insurance Program places on land south and southeast of lakes is clear.

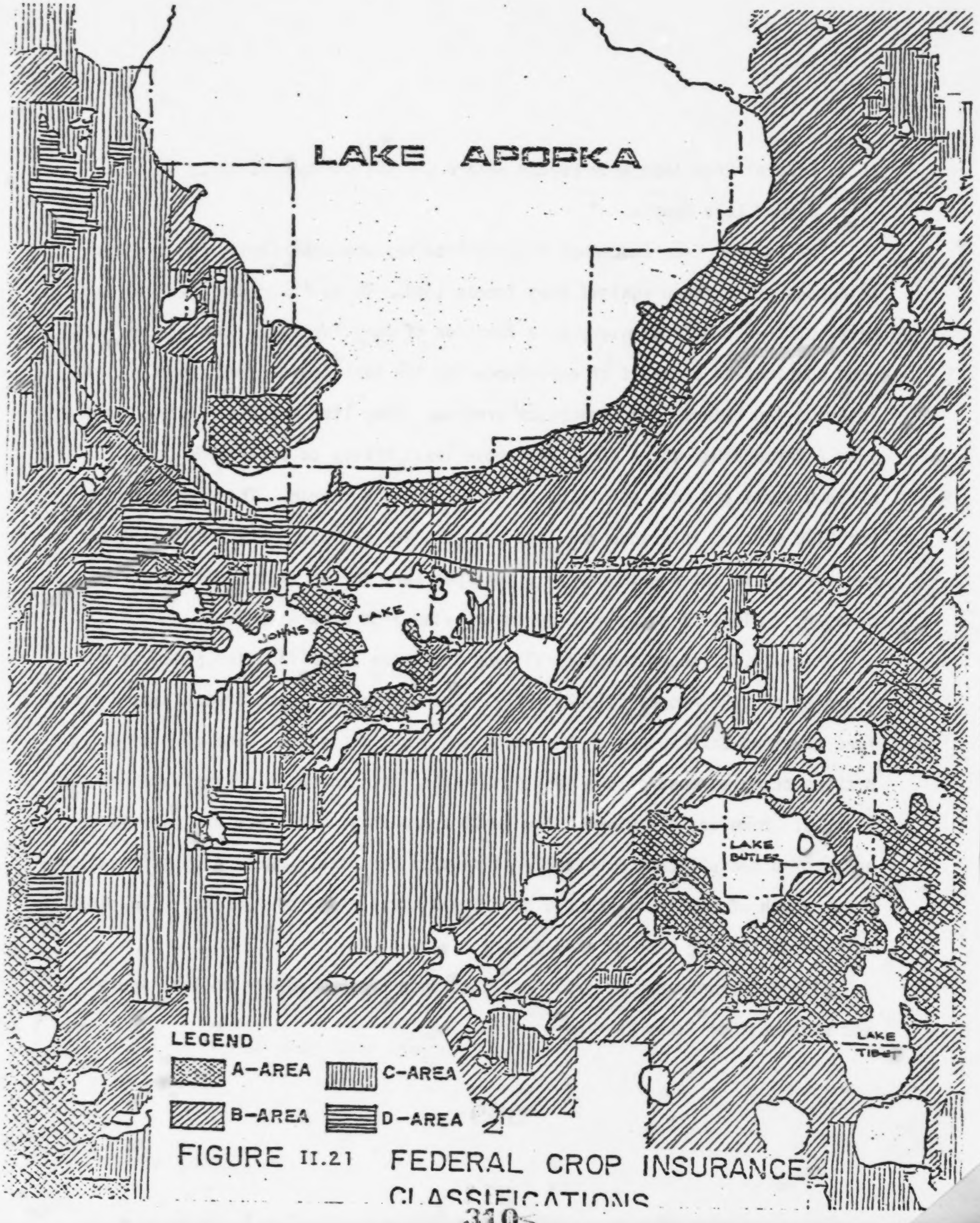

LAKE APOPKA
FLORIDA'S TURNPIKE
JOHNS
LAKE
LAKE BUTLER
LAKE TIBET
LEGEND
A-AREA
B-AREA
C-AREA
D-AREA

FIGURE II.21 FEDERAL CROP INSURANCE CLASSIFICATIONS

II.3 Analysis Of NOAA-3 Satellite Data.

The NOAA series of satellites pass over Florida approximately 10 p.m. most nights of the year. This satellite has a thermal scanner which has a resolution of about 1/2 mile on the ground. Thus it is possible to analyze the data from the NOAA satellite to determine temperature patterns in the vicinity of Lake Apopka.

On the night of 4 March 1975 with the general weather conditions which frequently occur during a radiation freeze, i.e. clear skies and wind speed of 3 to 6 m.p.h, we analyzed the temperature pattern from the NOAA satellite on Kennedy Space Center analysis facilities. Figure II.3.1 depicts general temperature patterns going from the coldest to the warm conditions in the central portion of the state surrounding Lake Apopka. The coolest temperatures shown are generally in low flat areas of little value for agricultural crops during the winter months. The temperature patterns are shown to gradually move into the better land occupied by hilly terrain. A specific ramification of this study was the cold temperature shown for the muckland north of Lake Apopka. The thermal properties of muckland will be discussed in detail in a later section. The muckland north of the lake is from 2 to 3 miles across from north to south. A cold surface of this size clearly results in cold air moving onto the lake from the north.

Figure II. 3.2 shows temperature patterns to be warmest around lakes and generally decreasing with distance. These clearly show that areas immediately around and south of lakes are the warmest. The next warmest areas are immediately out from the lakes and generally on the top of the ridge area of Florida. Fairly warm areas are even shown north of the mucklands.

Even though the exact temperatures in each zone are not known the temperature difference between the warmest and coolest areas is about 10°F. Although

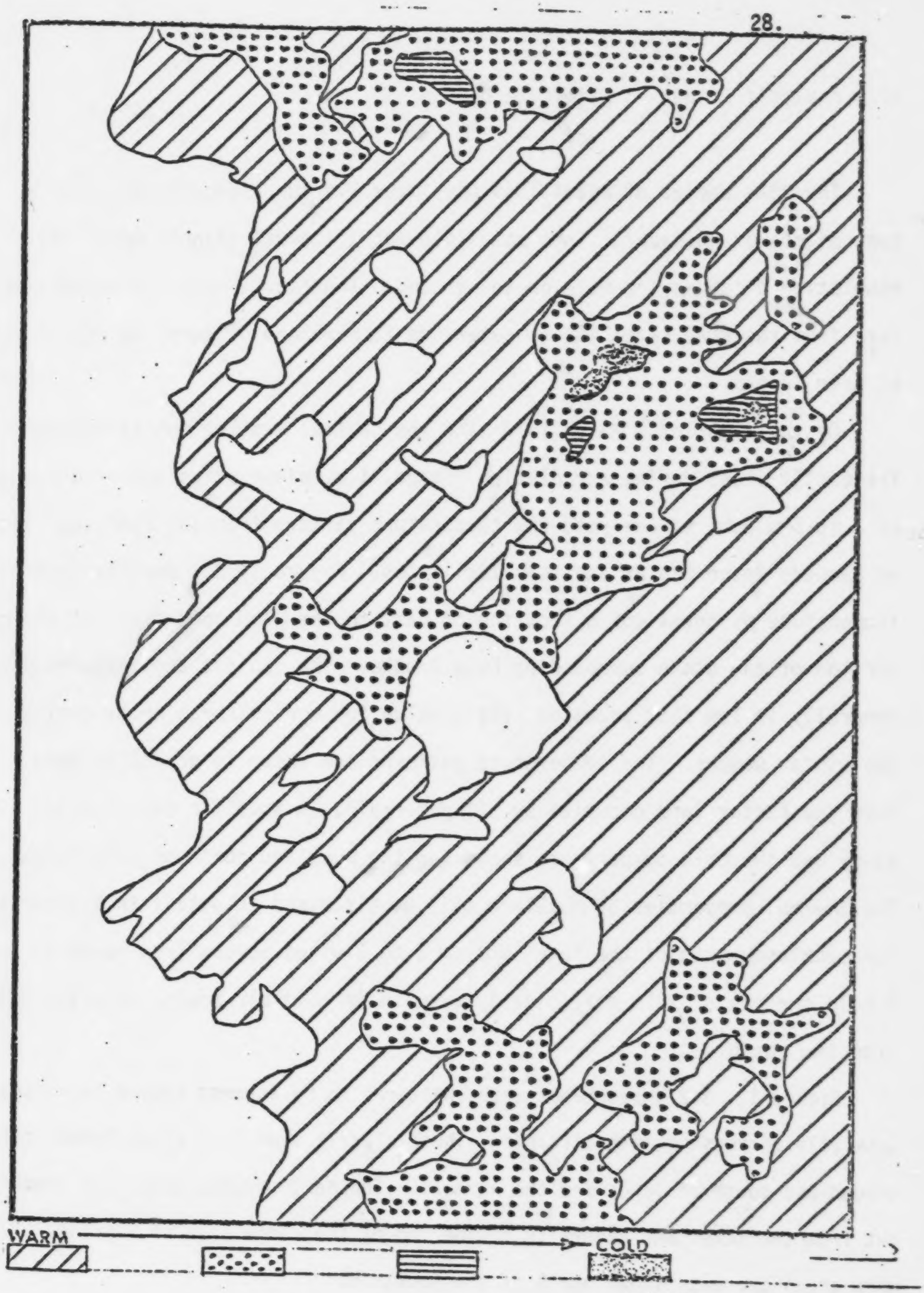

28.
WARM
COLD

Figure 11-3.1 NOAA Satellite data for March 4, 1975, cold pattern

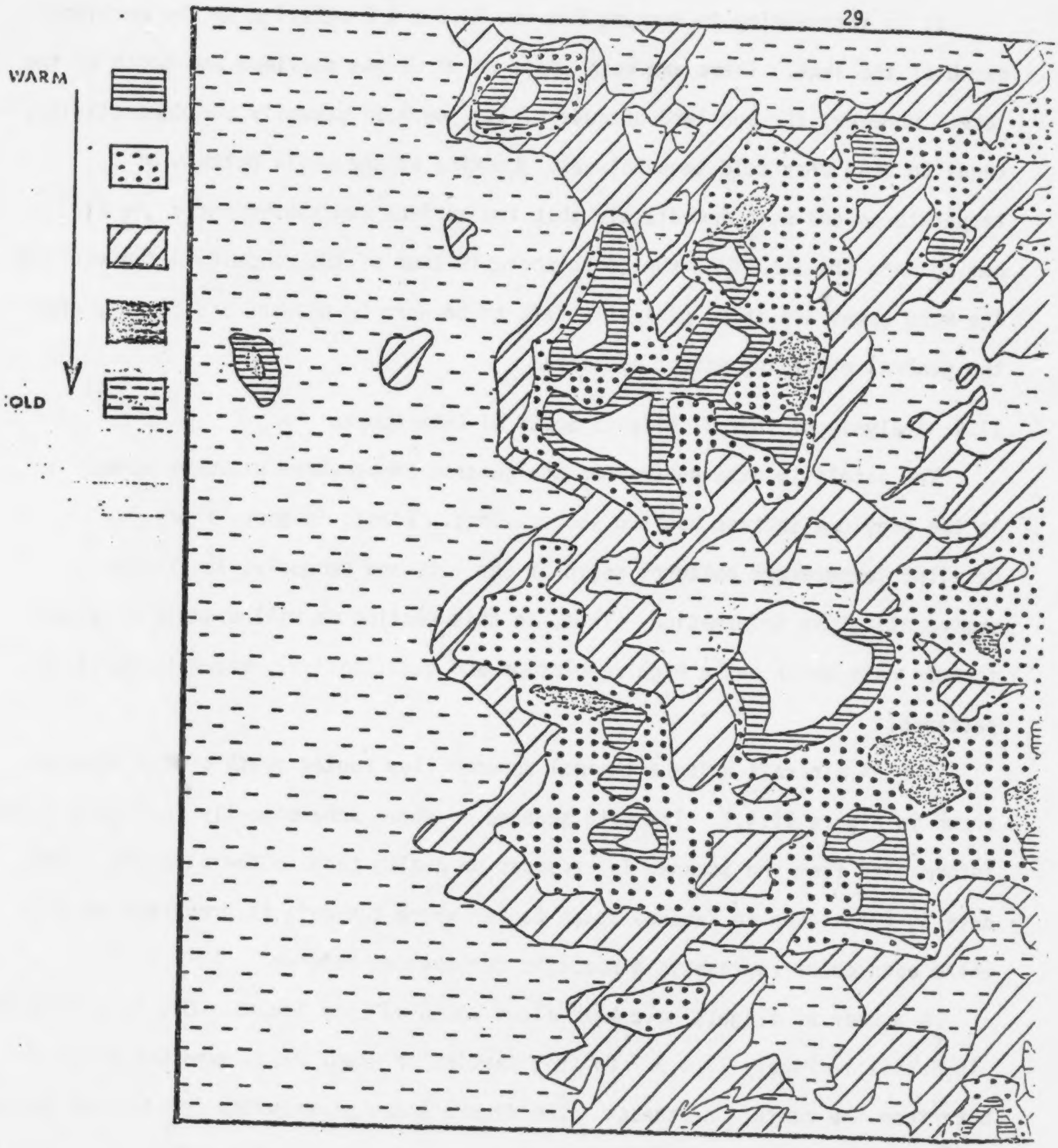


Figure 11-3.2 NOAA Satellite data for March 4, 1975, warm pattern

these temperatures are not truly quantitative they do clearly show temperature patterns in the whole vicinity of Lake Apopka.

It is interesting to compare Figures II.3.1 & 2 relative to the muckland north of the lake. There are warm areas north of the muckland and south of the lake. However, the muckland because of its low heat capacity and conductivity, tends to have very cold temperatures. Looking at the whole pattern of temperatures one sees immediately that the surface and subsequently the air [illegible] coming onto the lake from the north shore is some of the coldest in the vicinity The warm areas are those generally felt to be warm by growers and clearly show the general modifying effect of lakes.

II.4 Analysis Of Thermal Flights South Of Lake Apopka

The satellite data portraying the general temperature patterns shown in the previous section has two shortcomings. First, it doesn't provide detailed temperature patterns south of the lake and secondly, it is only semiquantitative information. Thus, in this section we will discuss airplane scanner data which has a high resolution and quantitatively shows temperature patterns.

A NASA aircraft using a thermal scanner flew routes south of the lake as shown in Figure II.4.1. The path scanned is shown schematically in Figure II.4.2 Information from the scanner is recorded on analog tape in the aircraft. This data is then taken to Kennedy Space Center where the data is processed on film where each color represents a specific temperature interval.

A number of flights have been flown south of Lake Apopka. One is portrayed in detail in Figure II.4.3. On this particular night winds were 5-8 miles an hour from the north - northeast. The figure shows clearly the temperature patterns south of Lake Apopka. The warmest bands of temperature are immediately south of the lake and the thermal effect from the lake appears to reach beyond the 4-miles covered with the thermal scanner. One sees clearly the plume effect from the warmed air moving over the land which modifies temperatures south of the lake

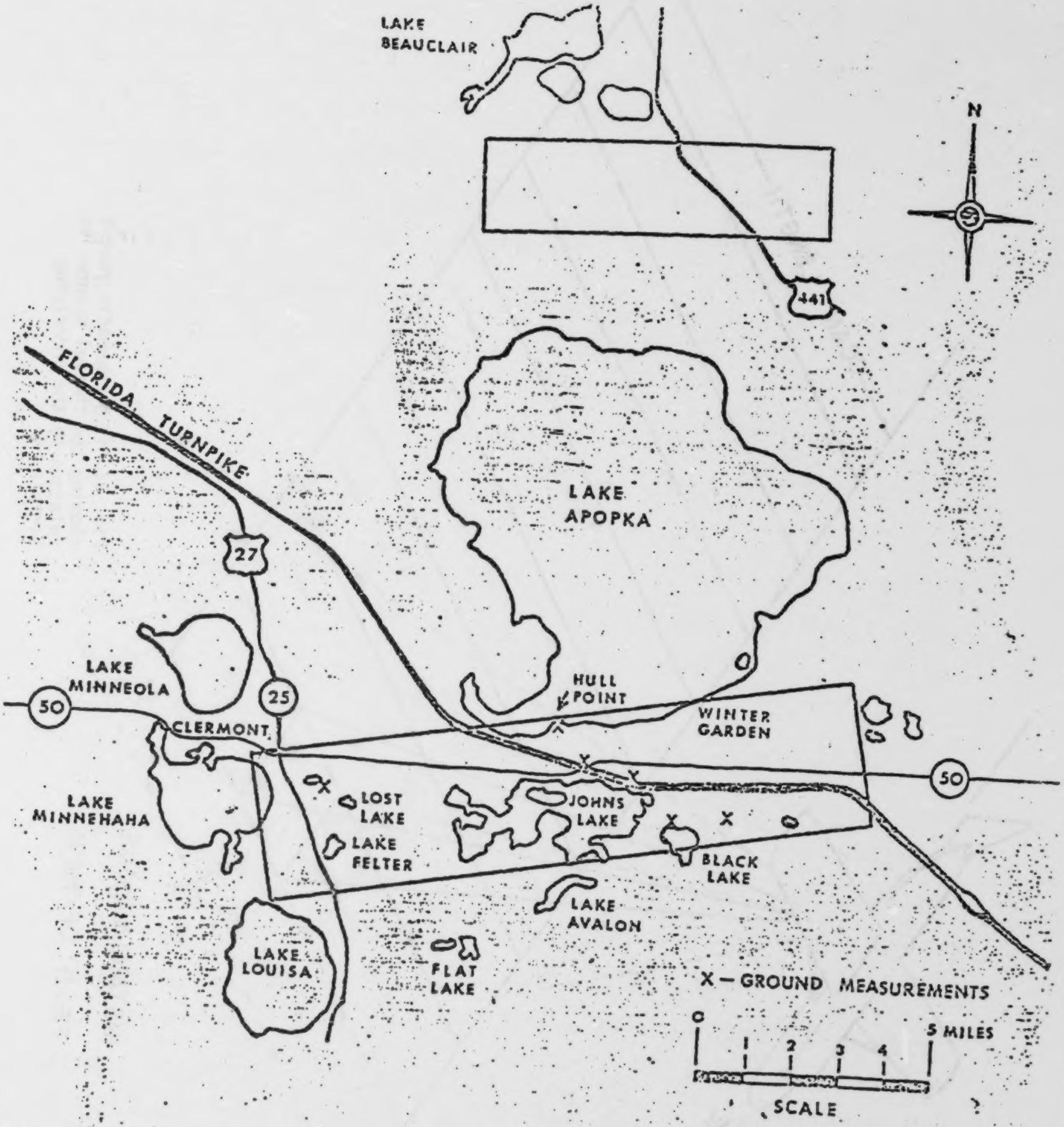

LAKE BEAUCLAIR
N
441
FLORIDA TURNPIKE
LAKE APOPKA
27
LAKE MINNEOLA
25
50
CLERMONT
HULL POINT
WINTER GARDEN
50
LAKE MINNEHAHA
LOST LAKE
LAKE FELTER
JOHNS LAKE
BLACK LAKE
LAKE AVALON
LAKE LOUISA
FLAT LAKE
X — GROUND MEASUREMENTS
0
1
2
3
4
5 MILES
SCALE

Fig. 14. General map of the L. Apopka area. The flight lines were contained in the general region at the south of the lake which is outlined although a single flight was made over the outlined area to the north.

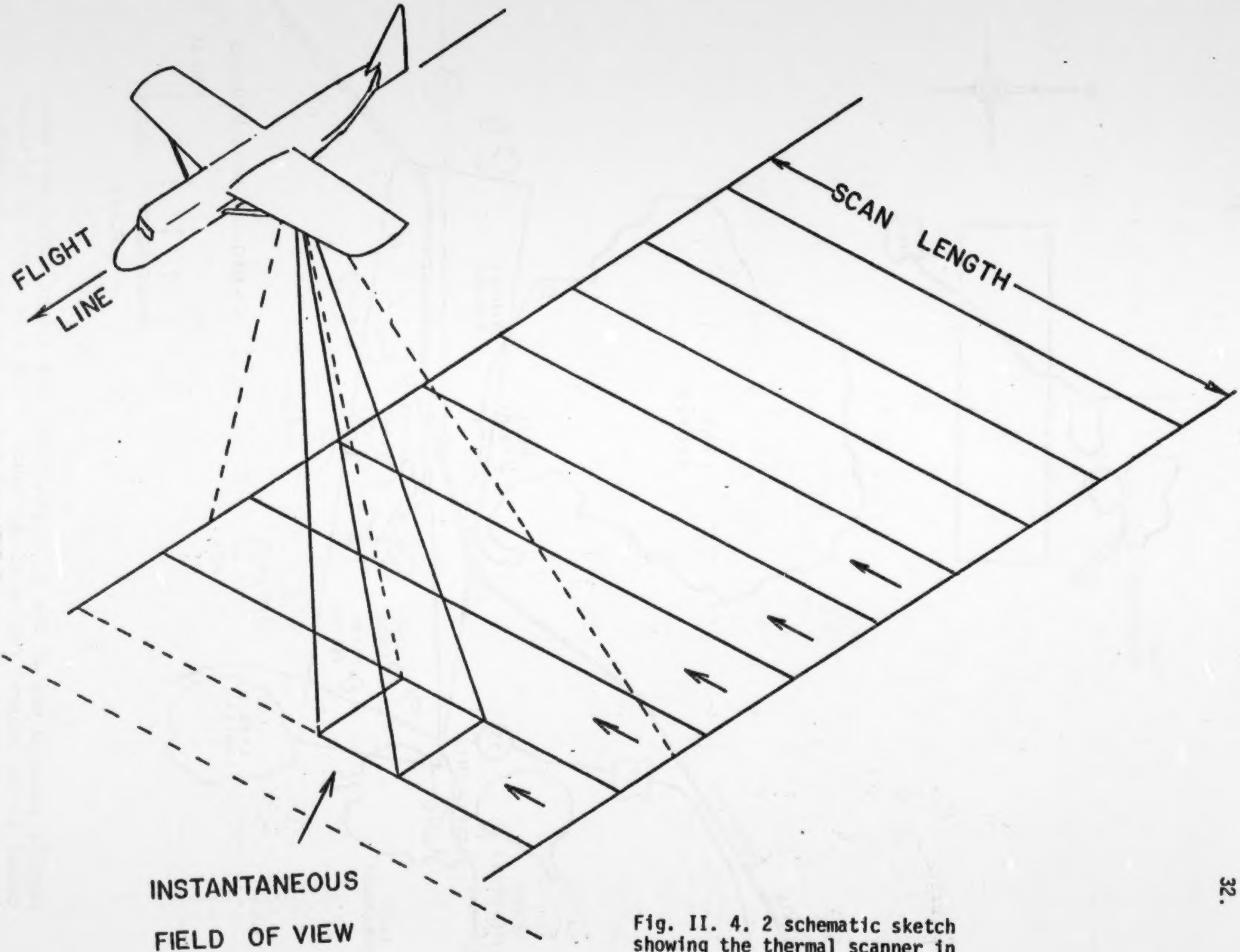

FLIGHT
LINE
SCAN LENGTH
INSTANTANEOUS
FIELD OF VIEW

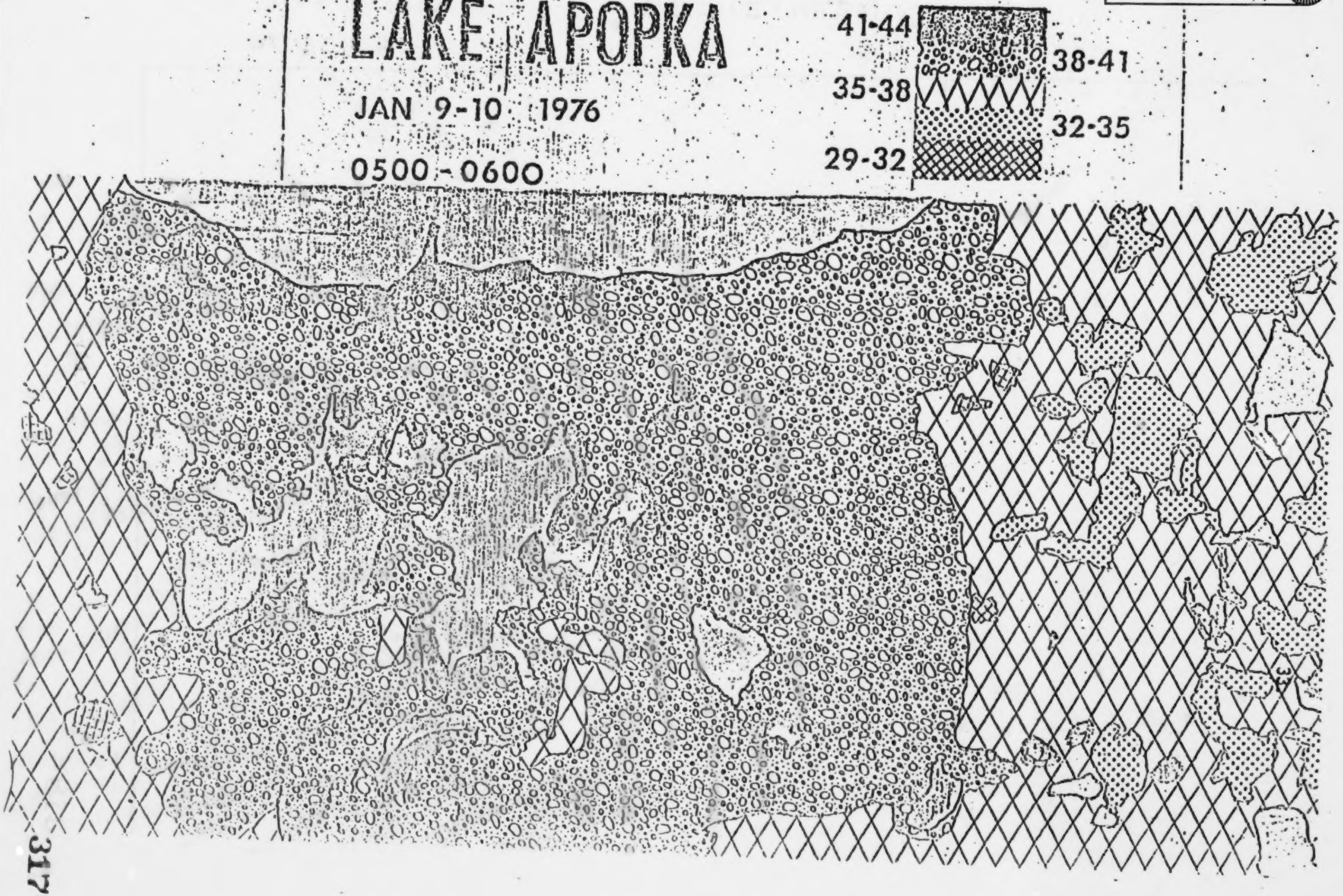
Fig. II. 4. 2 schematic sketch showing the thermal scanner in relation to the underlying terrain.

Reproduced from best available copy.

LAKE APOPKA

JAN 9-10 1976

0500 - 0600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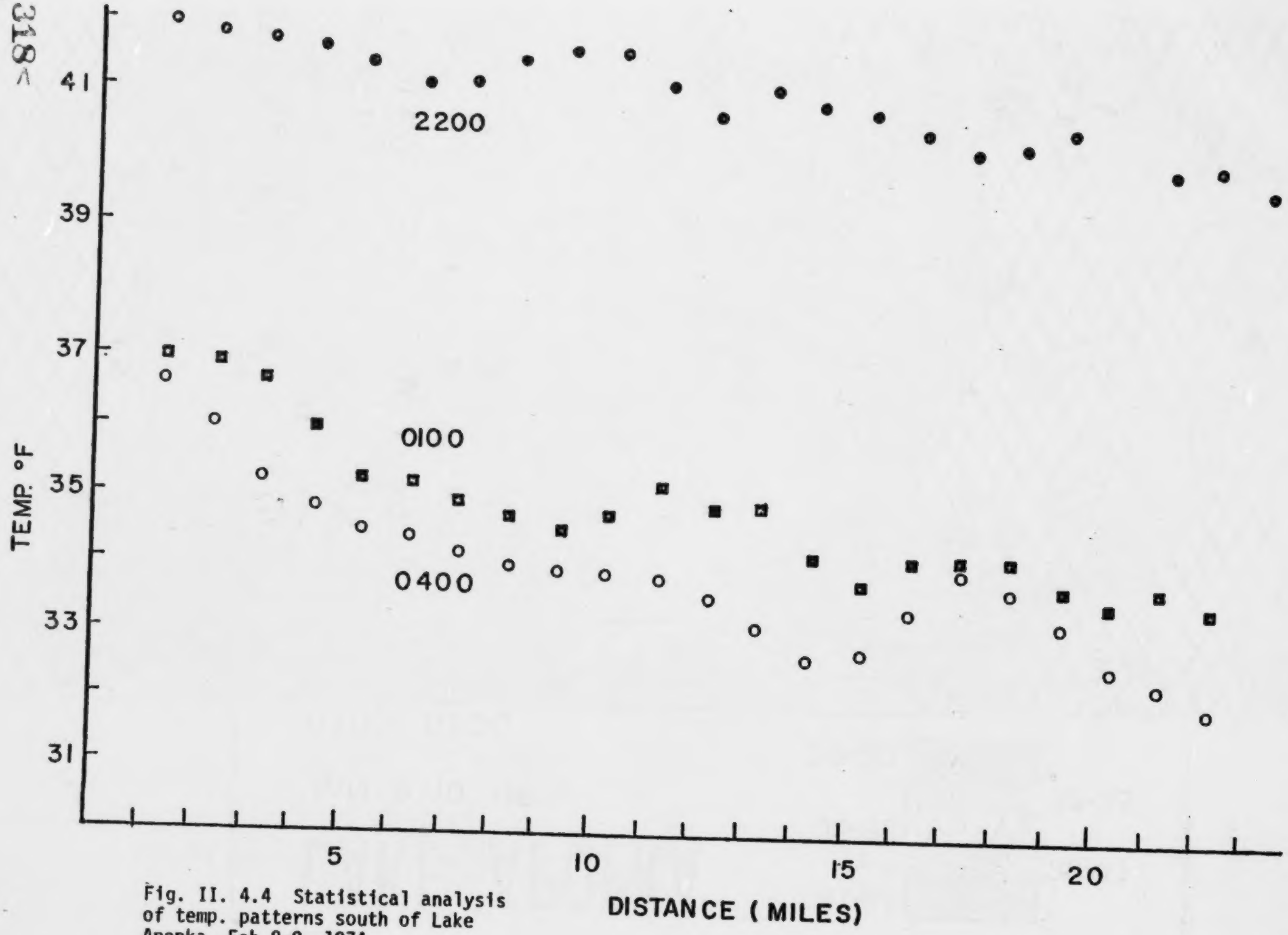

Fig. II. 4.4 Statistical analysis of temp. patterns south of Lake Apopka, Feb 8-9. 1974.

Temperatures both to the east and west of the plume effect are shown to be as much as 10° F cooler than similar land south of the lake. Thus, one can clearly see the dramatic temperature modification south of the lake from this composite of thermal scanner information.

We have also analyzed this type of data statistically. A grid was used to develop a matrix of temperatures south of the lake and the values were statistically analyzed. Only temperatures from similar type surfaces were used in the analysis and elevation effects were removed. This information in Figure II.4.4 shows the statistical analysis results from this study. Flights were made at 3 different times during this evening.

III.1. The Energy Balance of Lake Apopka

Introduction.

The thermal effects that were documented in previous sections result from the ability of the lake to store radiant energy received during the day and to release part of this energy to the air at night in the form of sensible and latent heat. The ability to store large quantities of energy stems from the relatively high heat capacity, c, of water and the large volume of water in the lake. Similar effects, although much larger in scale, are seen in coastal areas during the winter where convection currents from the warm oceans produce moderate temperatures as compared with those found on the inland continental land masses. In order to better understand these effects, the energy balance over land and over bodies of water is discussed below.

Following Munn (1966), figure III-1 and III-2 illustrate schematically the energy flow patterns found on land and on a lake for typical conditions during a "freeze period". Daytime conditions are shown in III-1 and nocturnal conditions are shown in III-2. During the day, the energy balance is quite similar for the land and lake cases. The net radiation, Rn, the resultant of long wave terrestial radiation and short wave solar radiation is a positive flux heating the soil and lake. Both the soil and water surfaces are typically warmer than the incoming air associated with the cold front. Furthermore, the vapor pressure of water, which increases with temperature, is also typically higher at the surface than within the air mass. Hence, some of the radiant energy received goes into increasing the temperature and relative humidity of the air. That is, the amount of radiant energy that the land and lake may absorb

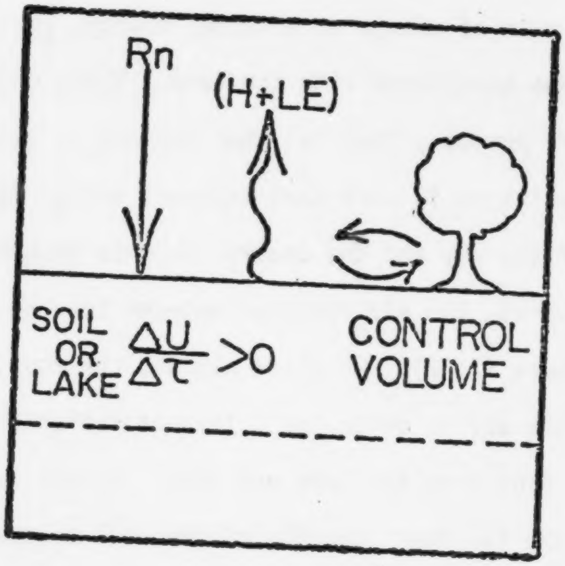
Rn
(H+LE)
SOIL OR LAKE
$\frac{\Delta U}{\Delta \tau} > 0$
CONTROL VOLUME

Figure 111-1 Daytime energy patterns over lake and land.

is reduced by the sensible heat, H, and latent heat flux, LE, to the air. In the case of the lake, another possible energy term is the heat flux received from the muck at the bottom of the lake. Calculations have indicated that, due to the small measured temperature gradient within the muck and its low thermal conductivity, this energy flux may be neglected. The net balance of the energy flux Rn+H+LE equals the time rate of change of internal energy, $\frac{\Delta u}{\Delta T}$ of the lake and control volume associated with the land. Thus, under conditions typical of freeze periods; that is, when the sky is clear, the intensity of solar radiation is such that internal energy increases with time for most of the day and the control volumes become warmer.

Close to sunset, the similarities between the two cases disappear rapidly (see Figure III-2). On clear nights, the equivalent black body temperature of the sky is quite low. The net radiation becomes a substantial energy flux from the lake and land. In the case of the land control volume the low heat capacity of the soil causes the soil surface temperature to rapidly decrease below the air temperature. Thus the land control volume receives energy in the form of sensible heat from the air. If the surface temperature falls to the dew point temperature then additional energy is gained from the latent heat released by the condensation of water vapor. Typically the sum of fluxes (H+LE+R) is less than zero and the land control volume decreases in internal energy ($\frac{\Delta u}{\Delta T}$<0). Obviously on clear nights when the outgoing net radiation flux is large, the danger of freeze damage is greatest.

In contrast to the rapidly falling temperatures within the land

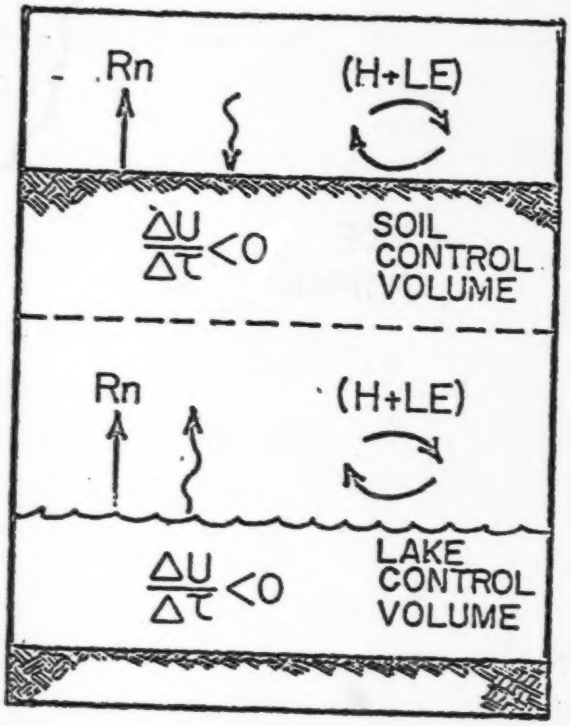
Rn
(H+LE)
$\frac{\Delta U}{\Delta \tau} < 0$
SOIL
CONTROL
VOLUME
Rn
(H+LE)
$\frac{\Delta U}{\Delta \tau} < 0$
LAKE
CONTROL
VOLUME

Figure 111-2 Nocturnal energy patterns.

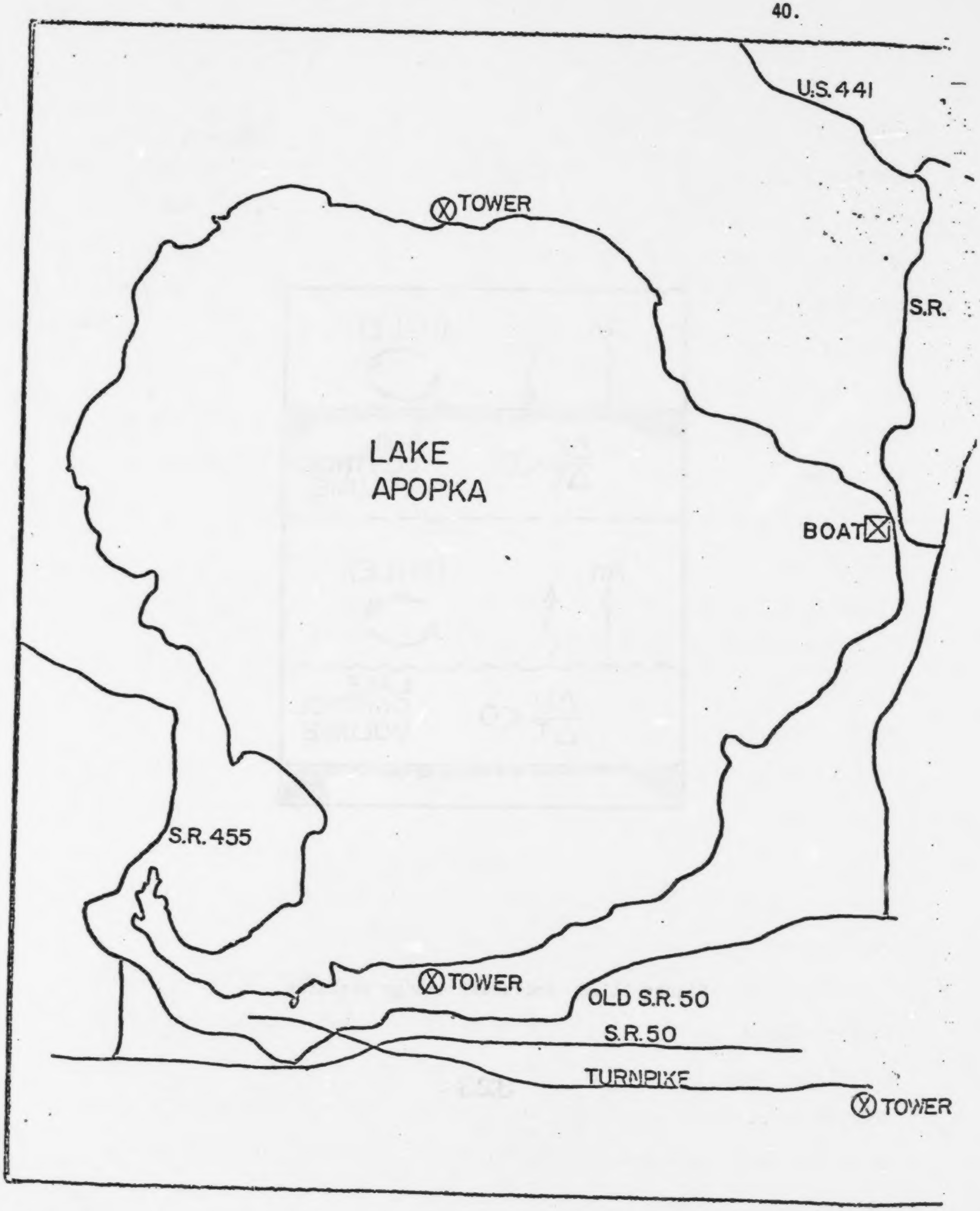
U.S. 441
TOWER
S.R.
LAKE APOPKA
BOAT
S.R. 455
TOWER
OLD S.R. 50
S.R. 50
TURNPIKE
TOWER

Figure III-3 Observation sites on Lake Apopka

control volume, the temperature of the lake on a "freeze night" is warmer than the air above. Energy leaves the lake as radiant energy as well as sensible and latent heat. The source for this energy flux is the stored internal energy at the lake, i.e. $(R+H+LE) = \frac{\Delta u}{\Delta \tau}$. The lake then contributes to an increase in the temperature and vapor content of the air moving over the lake. Since fronts associated with severe freezing conditions are usually dry air masses, the air advected downwind of the lake can increase the energy flux to the land control volume by increasing H through increasing air temperature and by increasing condensation, LE, by increasing the dew point temperature of the air.

Measurement of Energy Fluxes.

In addition to the surface temperature measurements discussed in previous sections, measurements of net radiation, air and lake temperatures, and relative humidity were obtained in an instrumented boat on Lake Apopka on the "freeze nights" of 19 January 1977 and 16 February 1977. Profiles of air temperature to a height of 15 m were also obtained for the night of 19 January 1977 at a single location north of Lake Apopka and at two locations south of Lake Apopka. The location of these observation points is shown in Figure III-3.

The instrumented boat provided by the Earth Resource Center of NASA (Kennedy Space Center) was located on the east of Lake Apopka since the prevailing winds for the two "freeze nights" were west to north-westerly. This location provided ample distance for the local surface boundary layer to become fully developed; hence, measurements from this location can be considered to be typical for most of the lake. The depth of the lake at this location was 1.70 m as compared to an average lake depth of 1.65 m. Instrumentation in the boat included a wet bulb-dry bulb psychrometer, an Atkins thermistor for measuring water temperature, an epoxy encased copper-constantan thermocouple for measuring muck temperatures, a Swissteco S-1 net radiometer, and a cup anemometer and wind vane. In order to estimate the amount of energy released by the lake through sensible and latent heat, instrumentation to determine the Bowen ration, $B=H/LE$, was mounted on a boom extending approximately 2 m beyond the bow of the boat. The Bowen ratio instrumentation consisted of a Brady array humidity sensing device and a 3 mil copper-constantan thermocouple referenced to an ice-water reference junction. The temperature and humidity array were attached to the belt of a pulley system and continuously traversed up and down a distance of approximately 1.5 m. The bottom point of the traverse was approximately 0.4 m from the mean surface level of the lake. The time for one complete traverse was 40 seconds. Changes in relative humidity and temperature levels were recorded continuously on Esterline Angus chart recorders. A switch at the top of the traverse triggered an event marker so that a record of the position of the array could be maintained. Calculated differences of vapor pressure and temperature across the 1.5 m traversed, coupled with measurements of net radiation and the rate of change of the lake temperature are used to estimate LE and H as below.

Briefly the Bowen ratio technique relies on the use of turbulent transport coefficients of heat, K_H, and vapor, K_V, (which are analogous to the thermal and mass diffusivities use in laminar flows), to estimate sensible and latent heat from vertical gradients of temperature, dt/dz and vapor density $d\rho v/dz$

$$B = \frac{H}{LE} = \frac{\rho c_p K_H \, dt/dz}{L K_v \, d\rho v/dz}$$

where ρ is the air density, c_p is the specific heat of air at constant pressure, and L is the latent heat of vaporization.

In finite difference form,

$$B = \frac{\rho C_p K_H \Delta t}{L K_m \Delta \rho v} .$$

Typically the transport of heat and mass are assumed to be the same, $K_H/K_m = 1$, (see Lemon, 1965). If Rn and $\frac{\Delta u}{\Delta \tau}$ are known then

$$LE = \frac{\frac{\Delta u}{\Delta \tau} - R_n}{1 + B}$$

$$H = \frac{B\left(\frac{\Delta u}{\Delta \tau} - R_n\right)}{1 + B}$$

The primary results for the freeze nights are detailed below.

In Figure III-4, the wind speed and direction, the 2 m air temperature, and specific humidity are plotted as a function of time for the period 0:00 - 5:30 EST, 20 Jan., 1977. The air temperature, t, and the specific humidity for the period are compared in Table III-1 with data supplied by NOAA from Gainesville and Orlando.

Table III-1. Air temperature and specific humidity for January 20, 1977.

Time (EST)	Gainesville temp (°C)	Gainesville humidity (g/kg)	Lake Apopka temp (°C)	Lake Apopka humidity (g/kg)	Orlando temp (°C)	Orlando humidity (g/kg)
00:00			1.1	3.1		
01:00	-5.6	1.8	0.6	2.3	-3.9	2.4
02:00			0.8	2.2	-4.4	2.3
03:00	-4.4	1.7	1.1	2.3	-5.0	2.2
04:00			-0.6	2.2	-4.4	2.3
05:00	-3.9	2.3	-1.1	2.3	-6.1	2.1

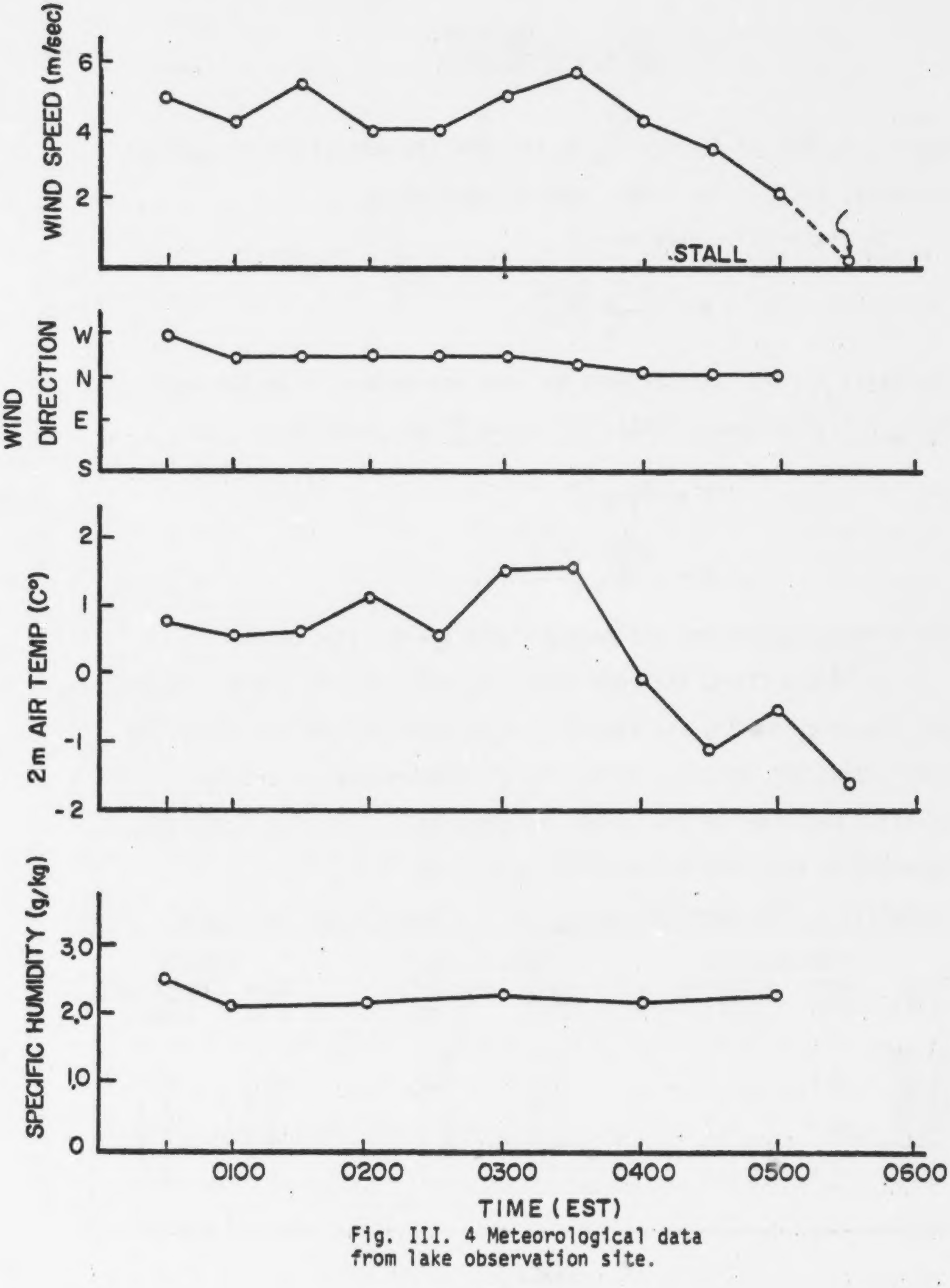

Fig. III. 4 Meteorological data from lake observation site.

Figure III-4 indicates that throughout most of the night the windspeed, air temperature, and specific humidity were relatively constant. The wind direction varied gradually from the west at 0:00 EST to the north at 4:00 EST. At wind speeds above approximately 4m/sec turbulent transport of sensible heat was sufficient to keep the temperature of the air mass moving across the lake above 0.5°C, This constrasts markedly with Orlando and Gainesville mean temperatures for this time period which were respectively -4.4°C and -4.6°C. The air temperature recorded for Orlando, shown in Table III-1, would seem to indicate that the temperature effects of Lake Apopka have been eliminated by diffusion by distances of the order of 20 K_m downwind of the lake. In constrast it appears that the effect on vapor content from Lake Apopka and smaller lake upwind of Orlando is still significant.

From 9:00 - 6:00 EST, the wind speed decreased until it was reduced below the stall speed of the cup anemometer (40cm/sec). The reduction in wind speed occurred simultaneously with the reduction in air temperature. This result is as expected since a reduction in wind speed would reduce the turbulent diffusivities hence the amount of sensible heat available to maintain the temperature of the air mass at an elevated level.

Figure III-5, a plot of temperature as a function of location with respect to Lake Apopka, indicates the effect of wind speed on turbulent transport even more dramatically. In Fig. III-5 temperature data is shown for the period of 02:18 - 03:13 EST and 05:48 - 06:11 EST for 20 Jan. 1977. From the time period of 02:18 -03:13 EST, the wind speed fluctuated between 4 and 5m/sec. Down wind of the lake a zone of warm air in comparison with regions east and west of the lake, is readily apparent. In contrast, for the time period of 05:48 - 06:11, when the

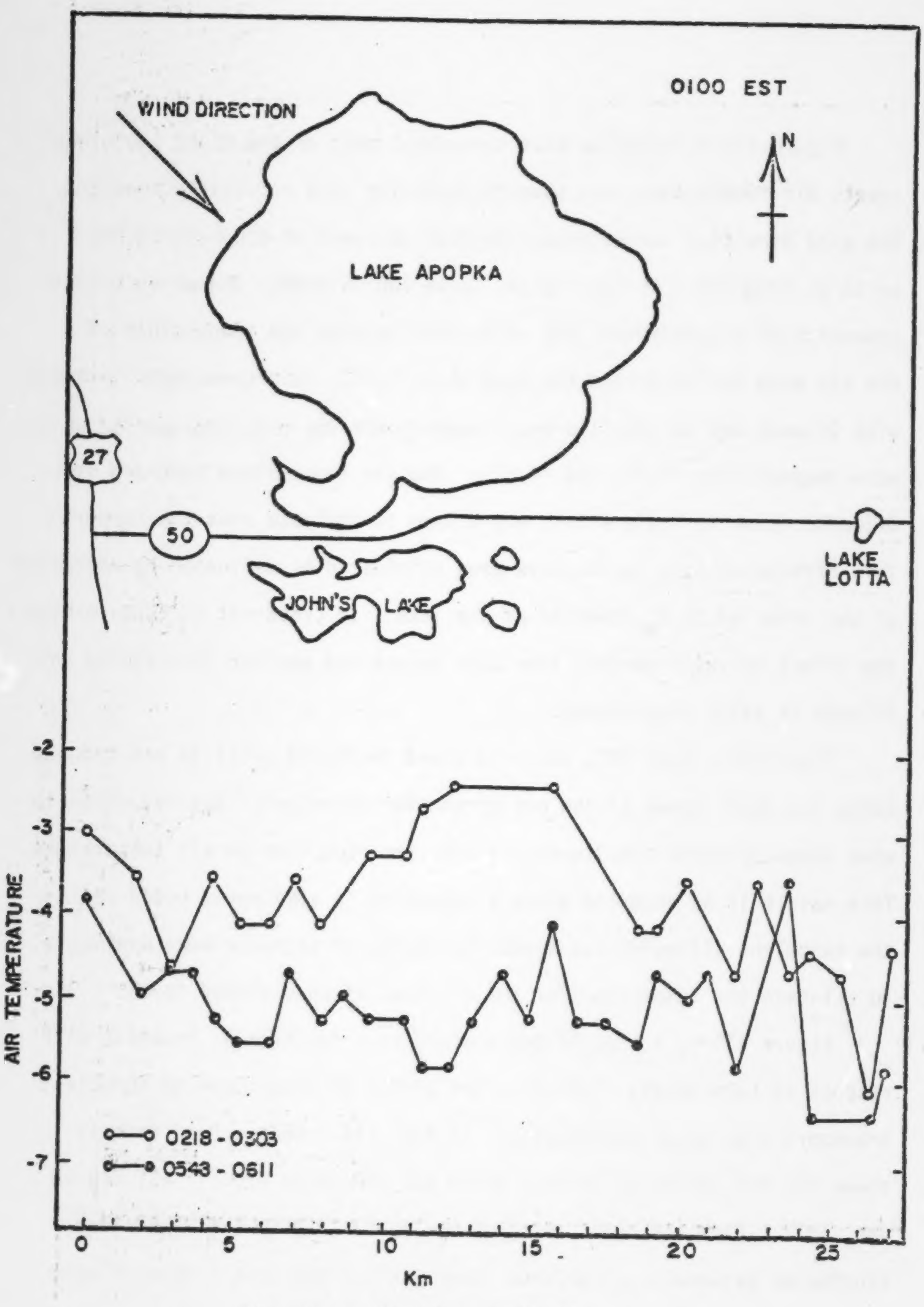

Fig. III.5 Air temp. south of
Lake Apopka for 20 Jan 1977.

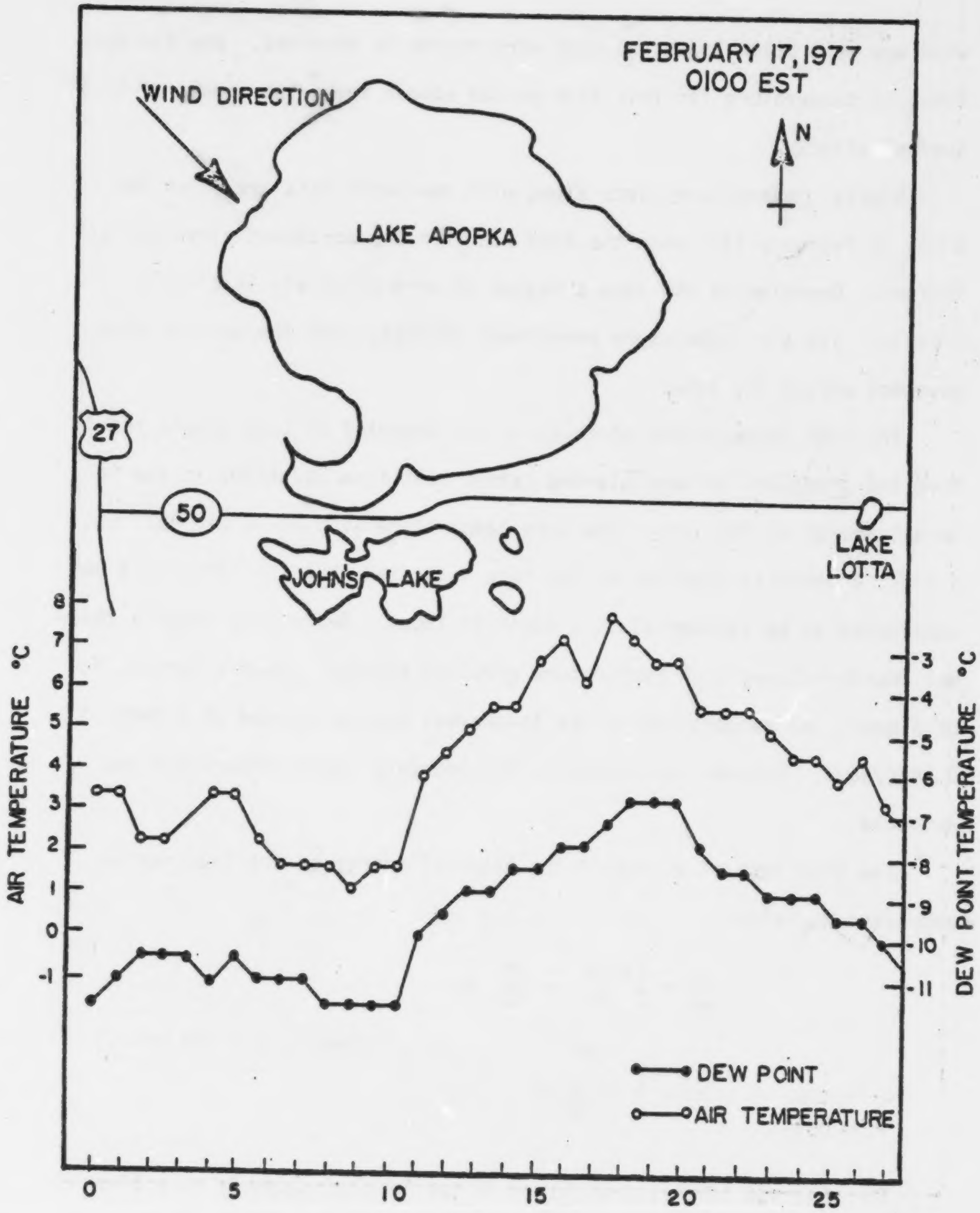

Fig.III. 6. Air and dew point temp. south of Lake Apopka for 17 Feb.77.

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wind was well below 1m/sec no such warm region is observed. The fluctuations in temperature for this time period appear to be the result of local thermal effects.

Similar temperature plots along with dew point data are shown for 01:00 16 February 1977 when the wind was from the northwest direction at $\approx$6m/sec. Downwind of the lake a region of warm moist air is clearly visible. The air temperature correlates strongly with the axis of wind movement across the lake.

The high temperatures observed on and downwind of Lake Apopka result from the transport of sensible and latent heat from reduction in the internal energy of the lake. The lake temperature at 0:00 20 Jan 1977 was 5.6°C. A vertical traverse of the lake indicated that the lake could be considered to be isothermal to a depth of 150cm. Below this level a thermal boundary layer with temperature gradient existed. Over a period, T, of 5 hours the temperature in the isothermal region changed at a rate of 0.14°C/hour. However, no change in the boundary layer temperature was detected.

The time rate of change of the internal energy of the lake may be expressed as below:

$$\frac{du}{d\tau} = \frac{1}{T} \int_0^d \rho c \frac{dT}{dz}\, dz$$

or (depth, d = 150 cm)

$$\frac{du}{d\tau} = \frac{1}{T} \rho c \frac{\Delta T}{\Delta\tau} d$$

The observed temperature change in the lake corresponds to a time rate of change of internal energy of 0.35 cal/cm^2-min. The net radiation, nearly constant, for this time period, was 0.20 cal/cm^2-min. Thus the energy available for sensible and latent heat was 0.15 cal/cm^2-min.

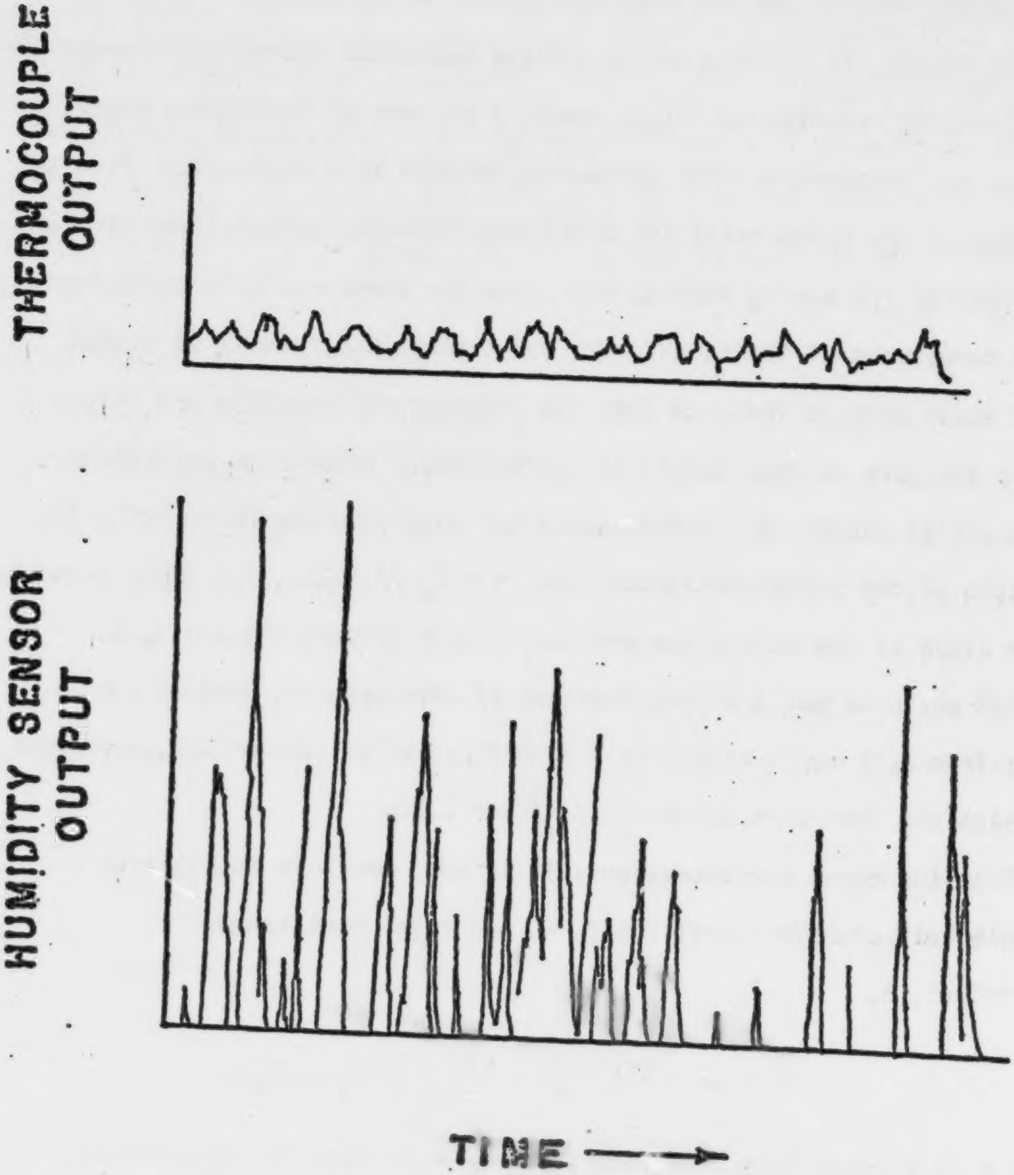


Figure III-7 Thermocouple and Brady array analog outputs from lake observation site.

An estimate of the ratio of sensible heat to latent heat for the period was obtained from the recorded analog outputs of the Brady array and thermocouple.

Typical results for the high wind period of 20 January 1977 are shown in Figure III-7. Increasing voltage indicates increasing temperature and increasing relative humidity, hence, a pattern of increasing vapor pressure and temperature with decreasing heights is discernable. Precise estimates of the Bowen ratio are difficult; however, calculations from an inspection of the analog records indicates the Bowen ratio is approximately 1.

A comparison of the result with the theoretical results of Penman (1948) would seem to indicate that the transport of sensible and latent heat at the lake surface occurs at approximately saturation conditions. Penman (1948) showed that under saturation condition the Bowen ratio is the ratio of the psychrometric constant, $\gamma = C_p P/.622L$, (P = total pressure), to the slope of the saturation pressure versus temperature curve, Δ. γ = .622 mb/°C is not a strong function of temperature. However, Δ varies from 0.46 mb/°C at 0°C to 1.9 mb/°C at 25°C. Under the conditions for which the data were taken $\frac{\gamma}{\Delta} = \frac{.66}{.549} = 1.2$.

From the above considerations, it is now possible to estimate a sensible heat transfer coefficient, h, and total heat transfer coefficient, h_T

$$H + LE = H(1 + \frac{\Delta}{\gamma}) = h(1 + \frac{\Delta}{\gamma})(t_\ell - t_a)$$

where t_ℓ = average lake temperature and t_a = average air temperature.

Taking $t_\ell = 5.6°C$ and $t_a = 1.1°C$

$$h = .018 \text{ cal/cm}^2\text{-min - °C}$$

These coefficients will be used below in discussing the energy balance of the lake during drawdown.

A Comparison of the "Lake Effect" with the "Urban Heat Island".

Thermal effects similar to those discussed above have been reported for many years in urban areas at night during the winter season. In these cases, the additional source of energy is supplied, not only through the release of internal energy, but by the waste heat added to the atmosphere by man's utilization of energy for industrial and residential purposes. As a comparison of the thermal sources related to the "lake effect" and the "urban heat island", we note that Bornstein (1968) reported that combustion during winter in Manhattan released a flux of heat of more than 0.28 cal/cm^2 -min. This is of the same order of magnitude as the released sensible and latent heat from Lake Apopka (0.15 cal/cm^2 -min over a ~115 Km^2 surface area). Thus one would expect to observe temperature modification patterns similar to those observed in urban areas.

A complete survey of the thermal effects of cities is given by Gutman (1974). Briefly the "urban heat island" in comparison with surrounding rural areas is characterized by increased surface temperatures, lower humidity, lower wind speeds, and increased turbulence. Bornstein (1968) reported, for Manhattan, elevated temperatures of about 4°C. No surface inversions were observed in contrast to suburban areas, however, a slight inversion elevated above the city was detected. Atwater (1971) has suggested that the elevated inversions may be due to the radiation characteristics of pollutants. Since water vapor absorbs long-wave radiation to a high degree, a similar inversion may exist over the "lake heat island".

A study by Preston-Whyte (1970) of the heat island surrounding Durban, South Africa has indicated that the center of the heat island may be displaced from the central business district by a sea breeze. Such an effect would be quite similar to the thermal effects observed under high wind conditions downwind of Lake Apopka. Angell et al. (1971), in a study of the Columbus, Ohio heat island, observed that advection of heat from the urban area to rural areas caused an elevated inversion quite similar to those observed south of Lake Apopka. Thus, the above discussion suggests that a model used to predict flow parameters for the "urban heat island" would with slight modifications be appropriate for predicting temperature and humidity profiles in the Lake Apopka region.

Numerous one-dimensional models of the "urban heat island" exist [see e.g., Estoque (1963) and Myrup (1969)]. However, these models inherently neglect advection terms and cannot give an accurate account of the downwind development of temperature and humidity. The two-dimensional model of Gutman (1974) was chosen since it was deemed to be the most coherent and complete model to date.

Gutman (1974) uses a finite difference scheme, internally consistent with conservation of mass momentum, and energy, to solve a set of differential equations including the Navier-Stokes equations, a turbulent diffusion equation for water vapor, and the heat equation for the soil substrate. Surface temperatures are not prescribed as boundary conditions; instead, they are predicted from an energy balance at the surface which is consistent with boundary conditions imposed at 1500 m and at a depth of 0.1 m in the substrate. Such a model should propriate for determining surface temperatures downwind of the as well as contours of temperature and humidity. Upwind conditions e varied to model changes in front conditions.

III. 2.The Modified Lake

The proposed drawdown of Lake Apopka, by reducing the total heat capacity of the lake, drastically decreases the ability of the lake to store energy while maintaining relatively stable temperatures. Certainly, a cursory inspection of the temperature field upwind of the lake, as discussed in Section II, indicates that the lake cannot be completely drained during the winter season without risking extensive freeze damage to crops south of the lake. Beyond this, the question concerning the volume of water necessary to provide adequate thermal protection is quite difficult and may be answered only in a probabilistic sense.

In order to determine the effect of decreased water volume on the fall of the lake temperature during the passage of a cold front, the data of 20 January 1977 was used to develop a one-dimensional time-dependent model of energy flow and lake temperature. The freeze of 20 January 1977, being quite severe, provides representative information on radiation and turbulent transfer coefficients under "worst case" conditions. The lake is assumed to be an isothermal body of constant depth, d, exchanging energy to the air in the form of radiation and latent and sensible heat. The bottom of the lake is assumed to be an adiabatic surface. The equations describing these conditions are developed below (notation as in the previous section).

From the first law of thermodynamics, at any time τ,

$$\rho c d \frac{dt_\ell}{d\tau} = R_n + (H + LE)$$

$$H + LE = h\left(1 + \frac{\Delta}{\gamma}\right)(t_a - t_\ell)$$

From temperature data taken from Orlando and the observations on the lake, the air temperature, $t_a = 2.2°C$ from 07:00 - 16:00 EST and $t_a = 1.1°C$ from 16:00 - 07:00 EST. The day temperature corresponds to the average daytime air temperature in Orlando.

The radiation term is separated into two functions. During the day (07:00 - 18:00 EST), a sinusoidal variation with a period, T, of 22 hours is assumed, that is $R_n = R_o \text{ Sin } (\frac{2\pi\tau}{T})$ where the amplitude R_o is chosen to give an average radiation for the 11-hour period of 0.44 cal/cm^2-min. This radiation constant corresponds to the average net radiation measured at the IFAS Horticultural Unit on January 22, 1977 during a clear day. Between 16:00 and 7:00 EST the net outgoing radiation is calculated as the difference between sky incoming radiation calculated from the equivalent black body sky temperature and the gray body radiation emitted by the lake surface. From the net radiation data of 20 January 1977, the equivalent black body sky temperature was calculated to be 242°K or -31°C. Thus, taking the emissivity, ϵ, of the lake to be 0.98

$$R_n = \sigma[(242)^4 - 0.98(t\ell + 273)^4]$$

where σ is the Stefan-Boltzman constant.

In finite difference form then, the equation for the lake temperature t_ℓ at time, $\tau + \Delta\tau$, in terms of the lake temperature at time t is:

$$t_\ell'(\tau + \Delta\tau) = \frac{\Delta\tau}{\rho c d}\begin{cases} R_o \sin(\frac{2\pi(\tau - 7)}{T}) + h(1 + \frac{\Delta}{\gamma})(t_a - t_\ell), & 07:00 \le \tau \le 18:00 \\ [242^4 - .98(t_\ell + 273)^4 + h(1 + \frac{\Delta}{\gamma})(t_a - t_\ell)], & 16:00 < \tau < 07:00 \end{cases}$$

The time step used for the calculations was one hour. Data collected since 1974 indicates that typically prior to the passage of a cold front, the lake temperature is approximately 10°C. Thus the algorithm was started with the initial condition $t_{\ell}(07{:}00) = 10°C$. The results of the calculation are shown for a 2-day period in Tables III-2,3,4 with $d = 150$, 100 and 50 cm respectively. These results and the assumptions leading to these results are discussed below.

An inspection of Table III-2 indicates that the one-dimensional model predicts relatively closely the patterns of lake temperatures observed during the passage of the cold front of 19-20 January, 1977. The 06:00 temperature for the second day is predicted to be 5.7°C while the observed lake temperature low was 5.6°C. The rate of temperature decrease for the second day between 24:00 and 05:00 was 0.18°C/hr. as compared with the measured rate of 0.14°C/hr.

The above discrepancy in the rate of decrease in temperature is due to the higher predicted levels of sensible and latent heat as compared with measured levels. These increased heat transfer levels were specifically incorporated into the model to take into account the dependence of the transfer coefficient, h, on downwind distance, χ. For a turbulent boundary layer on an isothermal flat surface, h is proportional to $\chi^{-0.2}$ (see e.g. Gebhart (1971)). It may easily be shown that the total coefficient, h, for an entire surface of length, L, is related to the local coefficient, h_L, at the end of the plate by the simple relation, $h = 1.25\ h_L$. Hence the transfer coefficient was augmented by 25%.

The effects of decreasing the total heat capacity of the lake is indicated in Tables III-3 & 4 where the average depth is taken as 100 and 50 cm respectively. Due to the smaller heat capacity of the lake, the variations in day and nighttime lake temperatures become greater with decreasing d. Higher temperatures in the day result in increased levels of latent and sensible heat. Increases in these modes of heat transfer reduce the proportion of radiant energy which may be stored during the day and which may then be available to be advected downwind of the lake at night.

At night, for the two day period, the temperature drop rate increases with decreasing d. For the case, d = 100 cm, the temperature drop rate on the second day between 24:00 and 06:00 is .23°C/hr. One might expect the temperature drop rate to decrease since the rate of energy loss by latent and sensible heat has decreased. However, the relatively constant radiation loss coupled with the sharply decreased heat capacity results in the higher predicted nighttime temperature drop-rates. Eventually as the temperature of the lake approaches the air temperature, the rate of temperature drop must decrease. However, while the lake temperature is in the range critical for freeze protection, our model indicates the temperature drop-rate for the lake increases with decreasing average lake depth.

For the case, d = 100 cm, the low temperature for the two day period was predicted to be 4.5°C. A more critical concern is the amount of energy that could be advected downwind of the lake, H + LE. From Tables II-2,3,4 the total latent and sensible energy was summed for the period 24:00 - 06:00 of the second day of the cold front. For the d = 100 cm case, the energy was reduced by only 22%. The effect of the decrease in advected energy on the air mass south of the lake will be discussed in the next section.

For the case d = 50 cm, by the sunrise of the second day, 06:00, the lake temperature has already fallen to 3.5°C. By 06:00 the following day, the temperature has been further decreased to 2.3°C. The latent and sensible heat released between 24:00 - 06:00 of the second day of the front is only 41% of the energy released in the d = 150 cm case, the model for the unmodified lake.

Table III-2. Lake temperature evolution with lake depth - 150 cm.

TIME	TEMPERATURE (°C)	H $\frac{\text{cal}}{\text{cm}^2\text{-min}}$	R $\frac{\text{cal}}{\text{cm}^2\text{-min}}$	LE $\frac{\text{cal}}{\text{cm}^2\text{-min}}$
7	10.000			
8	9.924	-.176	.195	-.210
9	9.921	-.174	.374	-.207
10	9.977	-.174	.522	-.207
11	10.075	-.175	.629	-.209
12	10.193	-.177	.684	-.213
13	10.308	-.180	.684	-.217
14	10.397	-.182	.629	-.222
15	10.443	-.184	.522	-.225
16	10.427	-.185	.374	-.227
17	10.341	-.185	.195	-.226
18	10.178	-.183	.000	-.223
19	9.904	-.204	-.234	-.247
20	9.638	-.198	-.232	-.236
21	9.378	-.192	-.230	-.226
22	9.126	-.186	-.228	-.216
23	8.880	-.181	-.226	-.207
24	8.641	-.175	-.225	-.198
1	8.408	-.170	-.223	-.190
2	8.181	-.164	-.221	-.182
3	7.960	-.159	-.220	-.174
4	7.744	-.154	-.218	-.167
5	7.534	-.149	-.217	-.160
6	7.329	-.145	-.215	-.153
**************	**************	**************	**************	**************
7	7.235	-.115	.000	-.120
8	7.220	-.113	.195	-.118
9	7.278	-.113	.374	-.117
10	7.393	-.114	.522	-.119
11	7.549	-.117	.629	-.122
12	7.724	-.120	.684	-.127
13	7.895	-.124	.684	-.132
14	8.040	-.128	.629	-.138
15	8.139	-.131	.522	-.142
16	8.177	-.134	.374	-.146
17	8.142	-.134	.195	-.147
18	8.031	-.134	.000	-.146
19	7.813	-.156	-.219	-.169
20	7.601	-.151	-.217	-.162
21	7.395	-.146	-.216	-.155
22	7.193	-.142	-.214	-.148
23	6.996	-.137	-.213	-.142
24	6.804	-.133	-.211	-.136
1	6.617	-.128	-.210	-.130
2	6.434	-.124	-.209	-.124
3	6.255	-.120	-.207	-.119
4	6.081	-.116	-.206	-.114
5	5.911	-.112	-.205	-.109
6	5.744	-.108	-.204	-.104

Table III-3. Lake temperature evolution with lake depth - 100 cm.

TIME	TEMPERATURE (°C)	H $\frac{\text{cal}}{\text{cm}^2\text{-min}}$	R $\frac{\text{cal}}{\text{cm}^2\text{-min}}$	LE $\frac{\text{cal}}{\text{cm}^2\text{-min}}$
7	10.000			
8	9.885	-.176	.195	-.210
9	9.882	-.173	.374	-.206
10	9.969	-.173	.522	-.206
11	10.116	-.175	.629	-.209
12	10.291	-.178	.684	-.214
13	10.459	-.182	.684	-.221
14	10.589	-.186	.629	-.227
15	10.649	-.189	.522	-.232
16	10.619	-.190	.374	-.235
17	10.482	-.189	.195	-.233
18	10.233	-.186	.000	-.228
19	9.820	-.205	-.234	-.249
20	9.424	-.196	-.231	-.233
21	9.043	-.187	-.229	-.218
22	8.678	-.179	-.226	-.204
23	8.327	-.171	-.223	-.191
24	7.990	-.163	-.221	-.179
1	7.665	-.155	-.218	-.168
2	7.353	-.148	-.216	-.157
3	7.052	-.141	-.214	-.147
4	6.762	-.134	-.212	-.138
5	6.482	-.127	-.210	-.129
6	6.213	-.121	-.208	-.120

****

TIME	TEMPERATURE (°C)	H $\frac{\text{cal}}{\text{cm}^2\text{-min}}$	R $\frac{\text{cal}}{\text{cm}^2\text{-min}}$	LE $\frac{\text{cal}}{\text{cm}^2\text{-min}}$
7	6.106	-.090	.000	-.088
8	6.118	-.088	.195	-.085
9	6.238	-.088	.374	-.086
10	6.444	-.091	.522	-.089
11	6.707	-.095	.629	-.095
12	6.995	-.101	.684	-.102
13	7.275	-.108	.684	-.110
14	7.512	-.114	.629	-.119
15	7.678	-.120	.522	-.126
16	7.750	-.123	.374	-.131
17	7.712	-.125	.195	-.133
18	7.558	-.124	.000	-.132
19	7.250	-.145	-.215	-.153
20	6.952	-.138	-.213	-.144
21	6.666	-.132	-.211	-.135
22	6.390	-.125	-.209	-.126
23	6.124	-.119	-.207	-.118
24	5.867	-.113	-.205	-.110
1	5.618	-.107	-.204	-.103
2	5.379	-.102	-.202	-.096
3	5.147	-.096	-.200	-.090
4	4.923	-.091	-.199	-.084
5	4.707	-.086	-.197	-.078
6	4.497	-.081	-.196	-.072

Table III-4. Lake temperature evolution with lake depth - 50 cm.

TIME	TEMPERATURE (°C)	H $\frac{\text{cal}}{\text{cm}^2\text{-min}}$	R $\frac{\text{cal}}{\text{cm}^2\text{-min}}$	LE $\frac{\text{cal}}{\text{cm}^2\text{-min}}$
7	10.000			
8	9.771	-.176	.195	-.210
9	9.773	-.170	.374	-.202
10	9.953	-.170	.522	-.202
11	10.248	-.174	.629	-.208
12	10.589	-.181	.684	-.219
13	10.904	-.189	.684	-.232
14	11.130	-.196	.629	-.245
15	11.212	-.201	.522	-.254
16	11.109	-.203	.374	-.257
17	10.798	-.200	.195	-.253
18	10.278	-.193	.000	-.240
19	9.448	-.206	-.235	-.250
20	8.685	-.188	-.229	-.219
21	7.983	-.171	-.223	-.191
22	7.334	-.155	-.218	-.167
23	6.734	-.140	-.214	-.146
24	6.177	-.127	-.210	-.128
1	5.659	-.114	-.206	-.112
2	5.177	-.103	-.202	-.097
3	4.727	-.092	-.199	-.084
4	4.307	-.082	-.196	-.073
5	3.914	-.072	-.193	-.063
6	3.545	-.063	-.190	-.054
******************	******************	******************	******************	******************
7	3.479	-.030	.000	-.025
8	3.650	-.029	.195	-.024
9	4.026	-.033	.374	-.027
10	4.562	-.041	.522	-.035
11	5.196	-.053	.629	-.047
12	5.862	-.067	.684	-.062
13	6.489	-.082	.684	-.079
14	7.012	-.097	.629	-.096
15	7.376	-.108	.522	-.111
16	7.539	-.116	.374	-.122
17	7.476	-.120	.195	-.127
18	7.184	-.119	.000	-.125
19	6.594	-.137	-.213	-.142
20	6.047	-.124	-.209	-.124
21	5.538	-.111	-.205	-.108
22	5.064	-.100	-.201	-.094
23	4.622	-.089	-.198	-.081
24	4.209	-.079	-.195	-.070
1	3.822	-.070	-.192	-.060
2	3.459	-.061	-.189	-.052
3	3.119	-.053	-.187	-.044
4	2.799	-.045	-.185	-.036
5	2.498	-.038	-.183	-.030
6	2.215	-.031	-.131	-.024

IV. Air Temperature Downwind of Lake Apopka

The following is a very brief discussion of the equations governing a 2-dimensional flow over the Lake Apopka region and the boundary conditions necessary for these equations.

The model consists of 3 layers, the soil substrate or lake surface, the constant flux layer and the transition layer. It is a 2-dimensional model where the ordinary Cartesian coordinate system is used. The X-axis is at all times aligned to the geostrophic wind, the Y-axis is considered infinitely long and the Z-axis is in the verticle direction.

In the transition layer, the Navier-Stokes equation governing the conservation of momentum is used. The final form of the momentum equation is:

$$\frac{\partial \zeta}{\partial t} + U\frac{\partial \zeta}{\partial X} + W\frac{\partial \zeta}{\partial Z} = f\frac{\partial V}{\partial Z} - \frac{g}{\theta_\infty}\frac{\partial \theta}{\partial X} + \frac{\partial^2}{\partial Z^2}(K\zeta) \qquad (0)$$

Where ζ is the y component of vorticity defined by $\zeta = \frac{\partial U}{\partial Z}$ (1)

θ is the potential temperature.

g is gravity.

$f = 2\Omega \sin \phi$ where f is the Coriolus parameter, Ω is the rotation of the earth and ϕ the latitude. K is the turbulent diffusion coefficient.

In arriving at this final form of the momentum equations, traditional boundary layer assumptions were made. The vorticity ζ is introduced to remove the pressure term introduced by the density. (See Byers, General Meteorology, pp. 255-259). In vector notation, the vorticity is defined as the curl of the momentum equation. The temperature, T, is replaced by the potential temperature, θ, by assuming adiabatic processes. That is:

$$\theta = T \left(\frac{1000}{P}\right) R/cp,$$

The boundary layer approximation is that the horizontal diffusion is small compared to vertical diffusion. The final assumption is that of incompressibility.

$$\Delta \cdot V = 0 \qquad (2)$$

The energy equation for an incompressible fluid in laminar flow is given by Schlichting (1968),

$$\rho c\left(\frac{\partial\theta}{\partial t} + u\frac{\partial\theta}{\partial x} + v\frac{\partial\theta}{\partial y} + w\frac{\partial\theta}{\partial z}\right) = \frac{\partial}{\partial x}\left(K\frac{\partial\theta}{\partial x}\right) + \frac{\partial}{\partial y}\left(K\frac{\partial\theta}{\partial y}\right) + \frac{\partial}{\partial z}\left(K\frac{\partial\theta}{\partial z}\right) + \mu\phi + Qrad \qquad (3)$$

where K is the thermal conductivity and ϕ is the thermal dissipation and μ is the kinematic viscosity of air, ρ the density of air, and Qrad is the flux due to radiation. For the 2-dimensional flow, the equation simplifies to:

$$\frac{\partial\theta}{\partial t} + u\frac{\partial\theta}{\partial x} + w\frac{\partial\theta}{\partial z} = \frac{\partial}{\partial z}\left(K\frac{\partial\theta}{\partial z}\right) + Qrad \qquad (4)$$

In the transport of water vapor, the quantity q, which is the absolute humidity is used. Thus, the equation for vapor transport is:

$$\frac{\partial q}{\partial t} + u\frac{\partial q}{\partial x} + w\frac{\partial q}{\partial z} = \frac{\partial}{\partial z} \; K\frac{\partial q}{\partial z} \qquad (5)$$

Note, the coefficient of turbulence, K, is assumed to be the same for transfers of momentum, energy and water vapor.

The y component of the cross wind momentum takes the form:

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + w\frac{\partial v}{\partial z} = -f(u-u_g) + \frac{\partial}{\partial z}\left(K\frac{\partial v}{\partial z}\right) \qquad (6)$$

where u_g is the geostrophic wind speed, and f the coriolus parameter.

The set of equations (0), (1), (2), (4), (5), (6) contains 6 unknowns, namely, u, v, w, ζ, θ, and q.

We now have to define K and Qrad in order for the system to be closed. K, the turbulence coefficient, is defined as:

$$K = \ell^2 \left|\frac{\partial u}{\partial z}\right| \begin{pmatrix} (1 + \alpha\overline{Ri}) \\ (1 - \alpha Ri)^{-1} \end{pmatrix} \text{ for } \begin{matrix} \overline{Ri} \leq 0 \\ \overline{Ri} = 0 \end{matrix} \quad (7)$$

where the windshear term $\frac{\partial u}{\partial z}$ is:

$$\frac{\partial u}{\partial z} = -\sqrt{\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2} \quad (8)$$

The eddy length scale ℓ is defined as:

$$\ell = \frac{K(z+z_o)}{1+\frac{K(z+z_o)}{\lambda}} \quad (9)$$

and

$$\lambda \quad \frac{.00027\, u_g}{f.} \quad (10)$$

α is a constant equal to -3 and is empirically determined by Estoque (1963). Richardson's number Ri is defined as

$$\overline{Ri} = \frac{g}{\theta} \frac{\left(\frac{\partial \theta}{\partial z}\right)}{\left(\frac{\partial u}{\partial z}\right)^2}$$

The flux Qrad, under nocturnal conditions is simply the resultant of long wave radiation at any level. The method of Zdunkowski and Johnson (1965) is employed in the model.

The Constant Flux Layer.

The constant flux layer is a region above the ground where the fluxes of energy, momentum and water vapor are constant with height. The height of the constant flux layer is important. If the layer is too thick, it will influence the accuracy of the prediction; if the layer is too shallow, it will be effective in deccupling the solutions from any dependence upon grid spacing. In this model, the constant flux layer goes to 10 meters high.

The basic principle of the layer is based mathematically on a friction velocity, u_*, a friction potential temperature θ_* and a friction himidity q_*. The equations are:

$$
\begin{aligned}
K\frac{\partial u}{\partial z} &= u_*^2 = \text{constant.} \\
K\frac{\partial \theta}{\partial z} &= u_*\theta_* = \text{constant.} \qquad (11) \\
K\frac{\partial q}{\partial z} &= u_*q_* = \text{constant.}
\end{aligned}
$$

The final form of the equation is:

$$\phi = \phi_o + \phi_h \left(\frac{\ln\left(\frac{z+z_o}{z_o}\right) + \frac{K}{\lambda} z}{\ln\left(\frac{h+z_o}{z_o}\right) + \frac{K}{\lambda} z} \right) \qquad (12)$$

Here ϕ is a dummy variable for profiles of u, v, θ, and q. The gradients of u, v, θ, and q are:

$$\frac{\partial \phi}{\partial z} = \phi_h \left(\frac{\frac{1}{z+z_o} + \frac{K}{\lambda}}{1_n\left(\frac{h+z_o}{z_o}\right) + \frac{K}{\lambda} h} \right) \qquad (13)$$

For a derivation of equation (12), see appendix II.

The Energy Consideration in the Surface and Substrate.

The soil surface heat balance is governed by the equation,

$$\text{Qrad} + \text{Qevap} + \text{S} + \text{Ha} = 0 \qquad (14)$$

where Qrad = radiative flux.

Qevap = evaporative flux by water vapor.

S = soil heat flux.

Ha = sensible heat flux to air.

Positive terms represent transfer of heat away from the surface.

Below the surface, the heat transfer is governed by the equation

$$\frac{\partial T}{\partial t} - K_g \frac{\partial^2 T}{\partial z^2} = 0. \qquad (15)$$

The above equation implied a one-dimensional conduction. This is allowable due to the large vertical temperature gradients when compared to the horizontal gradients. K_g, the substrate or soil diffusivity is assumed to be constant with depth. K_g changes by a small amount as the substrate changes from that of the rural area to the urban area.

In order to model Qevap., Gutman assumes that there are moisture available from vegetative surfaces and that this moisture represents a fraction M of the total at saturation, represented by the equation $q_o = M\ qss$. It is assumed that bare surface contributes nothing to the evaporation process and Qevap. is calculated from

$$Qevap = -A\ La \frac{\partial q}{\partial z}, \qquad (16)$$

where A represents the % area of land covered by vegetation, and La is the latent heat of vaporization of water.

Thus, by solving simultaneously equation (15), for the substrate layer, equation (14) for the surface, equation (12) for the constant layer and equation (4) for the transition layer, the temperature within an entire column can be found.

Boundary Conditions.

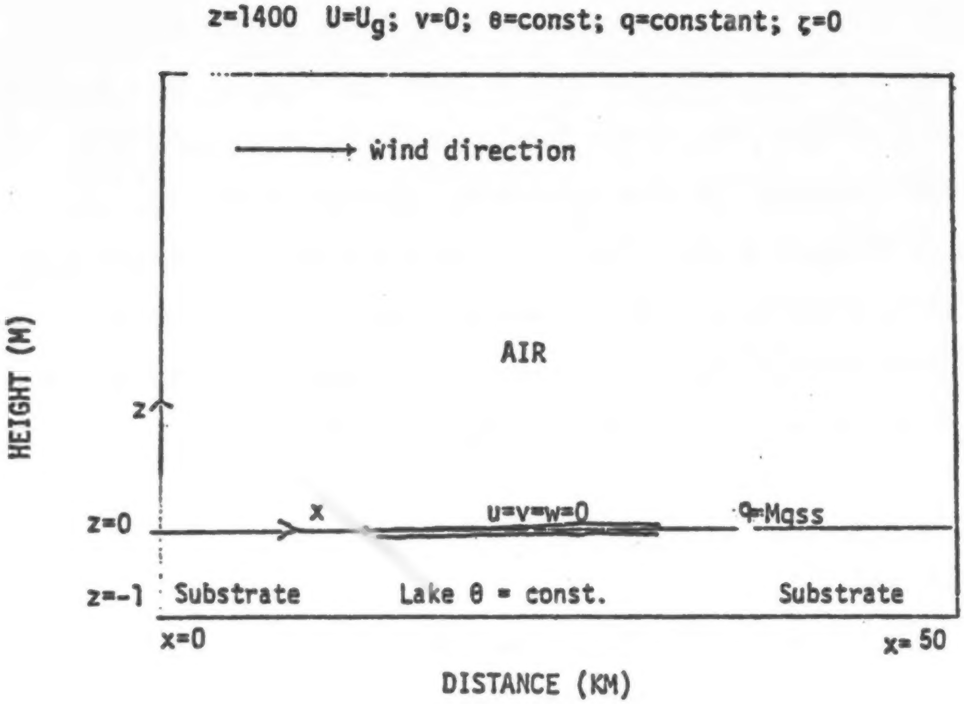
From the above discussions, all the necessary equations for solving the unknowns u, v, w, θ, q, ζ, K, and Qrad were given. Now, we turn to the boundary conditions. At z=0, u=v=w=0, this is to satisfy the no slip condition of a viscous fluid over a solid boundary surface.(see Fig. IV.1). Also, at z=0, some value of q is estimated q_o=Mqss. At the top of the boundary layer, at Z=H, U=U_g, the wind is specified to equal the geostrophic wind, and V=0 so that ζ=0, and the absolute humidity q=constant, also the upstream condition, the flow is uniform, and that at X=0, the lake perturbation is equal to zero. Actually, in this model, the uniform terraine model is first solved, so that the solution, that of a uniform steady flow is obtained and this solution is then applied as the initial boundary condition of the 2-dimensional model.

Numerical Methods.

1. Grid Systems

When calculating boundary layer flow, the largest gradient generally occur near the surface, thus, the more finely spaced grid points are placed near the surface; also the horizontal gradient is largest over the urban heat island area, thus, the more finely spaced grid points are also placed there.

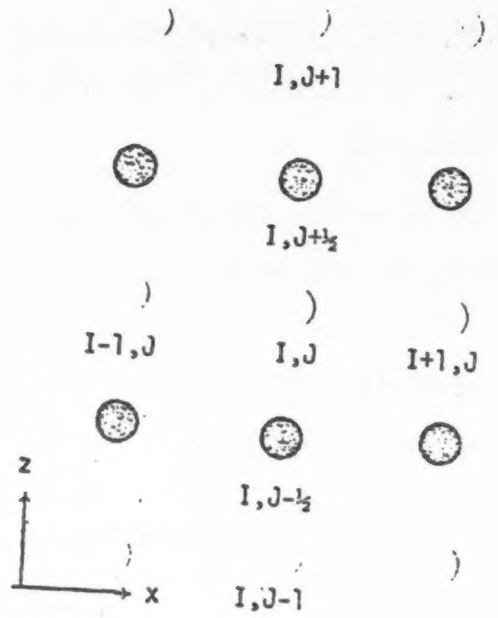
The variables u, v, w, θ, and g are all placed on the same grid points. The vorticity ζ is expressed as a derivative of u and therefore it is desirable to place ζ at grid point vertically displaced from u. The K model which is also based on vertical derivatives of variables, therefore is placed on the same grid point as ζ. Fig.IV.2 shows the grid.


z=1400 U=Ug; v=0; θ=const; q=constant; ζ=0
wind direction
HEIGHT (M)
AIR
z
z=0
x
u=v=w=0
q=Mass
z=-1
Substrate
Lake θ = const.
Substrate
x=0
x= 50
DISTANCE (KM)

At $x=0$, $\frac{\partial}{\partial x} = 0$

$w = 0$

Fig. IV.1. COMPUTING REGION AND BOUNDARY CONDITIONS


I,J+1
I,J+½
I-1,J
I,J
I+1,J
z
I,J-½
x
I,J-1

SYMBOL	VARIABLES AT THIS LOCATION
)	u,v,w,θ,q
○	ζ,K

FIG. IV. 2. GRID SYSTEM

2. Finite Difference Formulations.

The equations are formulated centering on I, J. The convective derivatives

$$u\frac{\partial\phi}{\partial x} + w\frac{\partial\phi}{\partial z} = \frac{\partial}{\partial x}(u\phi) + \frac{\partial}{\partial z}(w\phi)$$

where $$\frac{\partial(u\phi)}{\partial x} = \frac{1}{\Delta x}\left(\begin{array}{l} \bar{u}(I+\tfrac{1}{2}, J)\,\phi(I, J,) - \bar{u}(I-\tfrac{1}{2}, J)\,\phi(I-1, J) \\ \bar{u}(I+\tfrac{1}{2}, J)\,\phi(I+1, J) - \bar{u}(I-\tfrac{1}{2}, J)\,\phi(I, J) \end{array}\right) \begin{array}{l} \text{for } \bar{u} \geq 0 \\ \text{for } \bar{u} < 0 \end{array}$$

and $\bar{u}(1+\tfrac{1}{2}, J) = \frac{1}{2}[u(I+1, J) + u(I, J)]$.

Similarly, an equation can be written for $\frac{\partial}{\partial z}(w\zeta)$ (see Gutman, p. 48). Finally, Δx and Δz, representing the size of the control volume around the point (I, J) where

$$\Delta x = \tfrac{1}{2}[x(I+1) - x(I-1)]$$

$$\Delta z = \tfrac{1}{2}[z(J+1) - z(J-1)]$$

3. Numerical Results

The numerical simulation discussed in the previous section was evaluated for the following 4 critical cases: (1) the unmodified lake under high wind conditions, (2) the unmodified lake under low wind conditions, (3) the modified lake (average depth = 1m) under high wind conditions and (4) complete drawdown conditions. In order to simulate the Lake Apopka region, physical parameters, such as soil diffusivities, and boundary conditions, such as the 100 cm soil temperatures, needed to be specified. These particular parameters are given in Table IV.1. The soil diffusivities were calculated from Van Wijk (1966) and roughness parameters were obtained from Chang (1960). The temperature and moisture at the top of the boundary layer (1400 m) were supplied by the National Weather Service, Ruskin, Florida. Temperatures for the lake were supplied from measurements and from the results of the one-dimensional model discussed above.

The one-dimensional model indicated that under typical cold front conditions the lake temperature would be reduced by only about 1°C if the average depth of the lake was 1 m. In terms of the sensible and latent heat transported from the lake, a drawdown to 1 m would result in a 22% reduction in energy. The relationship between average lake depth and energy transported from the lake is shown in Figure IV.3.

The net effect on downwind air temperature due to a change in the lake temperature is related to the reduction in energy transported from the lake and to possible changes in the trajectory of the thermal plume from the lake. As the lake temperature decreases, less energy is available to be advected downwind. However decreasing lake temperature also acts to decrease the vertical ascent of the air mass across the lake. This occurs in two ways: (1) decreases in air temperature increases the air density and (2) the reduced temperature of the lake reduces the transport of water vapor

Table IV.1

Temperature at the bottom of the soil substrate: 11.5°C

Potential temperature at the top of the boundary layer: 2°C

Moisture content at the top of the boundary layer: 0.35 g/kg

Upwind roughness parameter: 0.01 m

Lake roughness parameter: 0.06 m

Downwind roughness parameter: 0.6 m

Muck diffusivity: $7.4\text{X}10^{-7}$ m^2/sec

Sand diffusivity: $1.15\text{X}10^{-6}$ m^2/sec

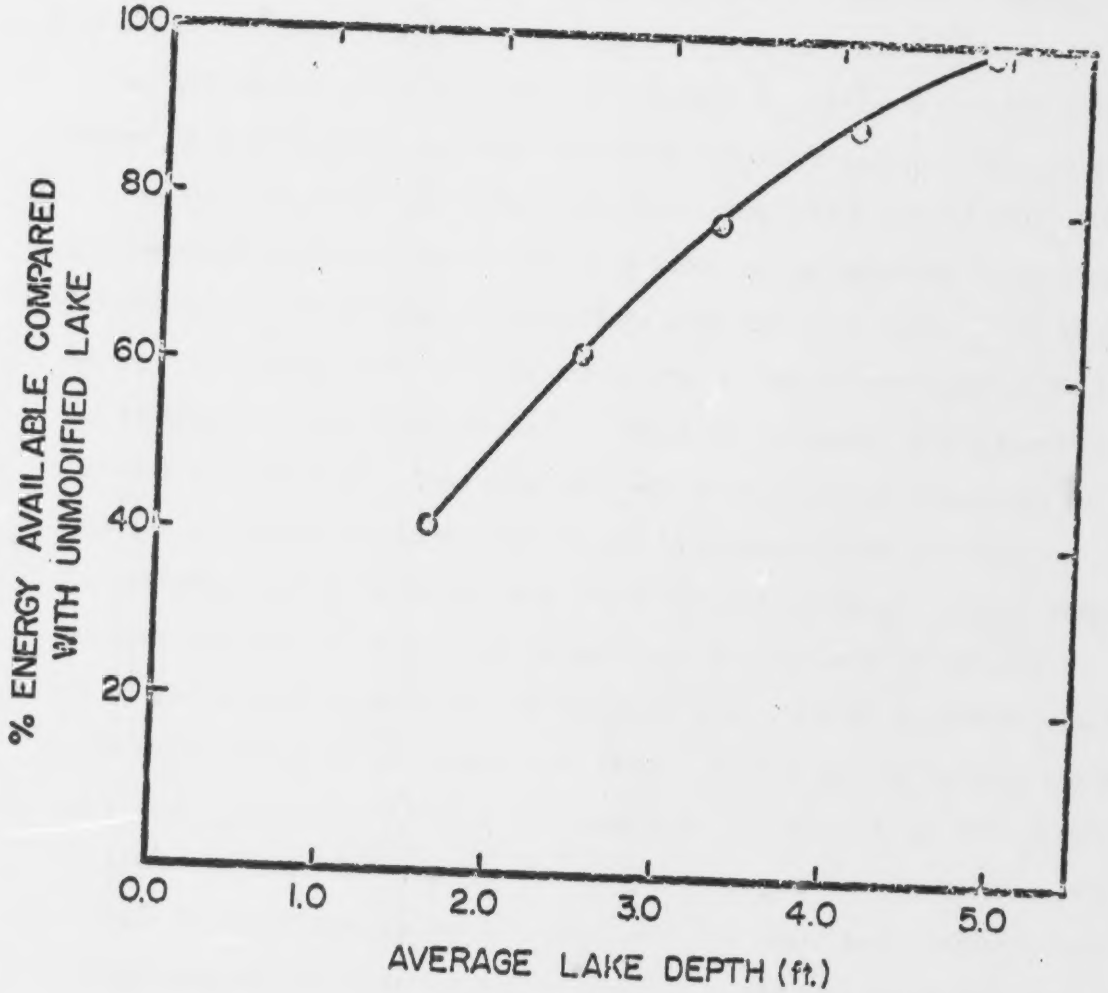


Fig. IV. 3 Energy transported from lake as a function of depth.

which is quite buoyant. Thus there are two competing mechanisms to consider when analyzing the effects of decreased lake temperature.

The results of the model are most easily seen in terms of Figures IV.4 and 5 in which surface temperature vs downwind distance and air temperature vs downwind distance are plotted respectively. In order to check the validity of the model, conditions simulating a high wind condition (5.4 m/sec) and a low wind condition (2.3 m/sec) were run with a lake temperature of 5.6°C. This corresponds to the conditions observed the morning of 20 January 1977. (see Section III). Under high wind conditions the surface and air temperature predicted by the model at a location corresponding approximately to SR 50 is -2°C. Under low wind conditions the temperature is approximately -4.5°C. These results are in good agreement with the measured results shown in Figure III-5. Although the model is a steady-state model, it appears to simulate conditions downwind of the lake quite well. This may be explained in terms of the rapid response of the air temperature to changes in the wind speed (Figure III.4) and the relatively slow variation in lake temperature.

In order to simulate the condition of drawdown to 1m, the lake temperature was reduced to 4.5°C (see Table III-3), the coldest temperature for the 2 day simulation. As seen in Figures IV.4 and 5, the net effect is to decrease both the air and surface temperature by about only 0.5°C. Such a decrease would probably not seriously affect growers. Next the lake under total drawdown conditions was simulated. It was assumed that soil along the lake bottom would have the same thermal characteristics as the muckland north of the lake. Under low wind conditions, the effect is quite dramatic. The low diffusivity of the organic soil acts to insulate the surface. The lake bed then becomes the coldest area in the region. At the southern edge of the lake, the model indicates the temperature to have dropped to -6.3°C. The model predicts that the thermal effect of an extended muckland created by complete drawdown would extend 5 km from the present edge of the lake.

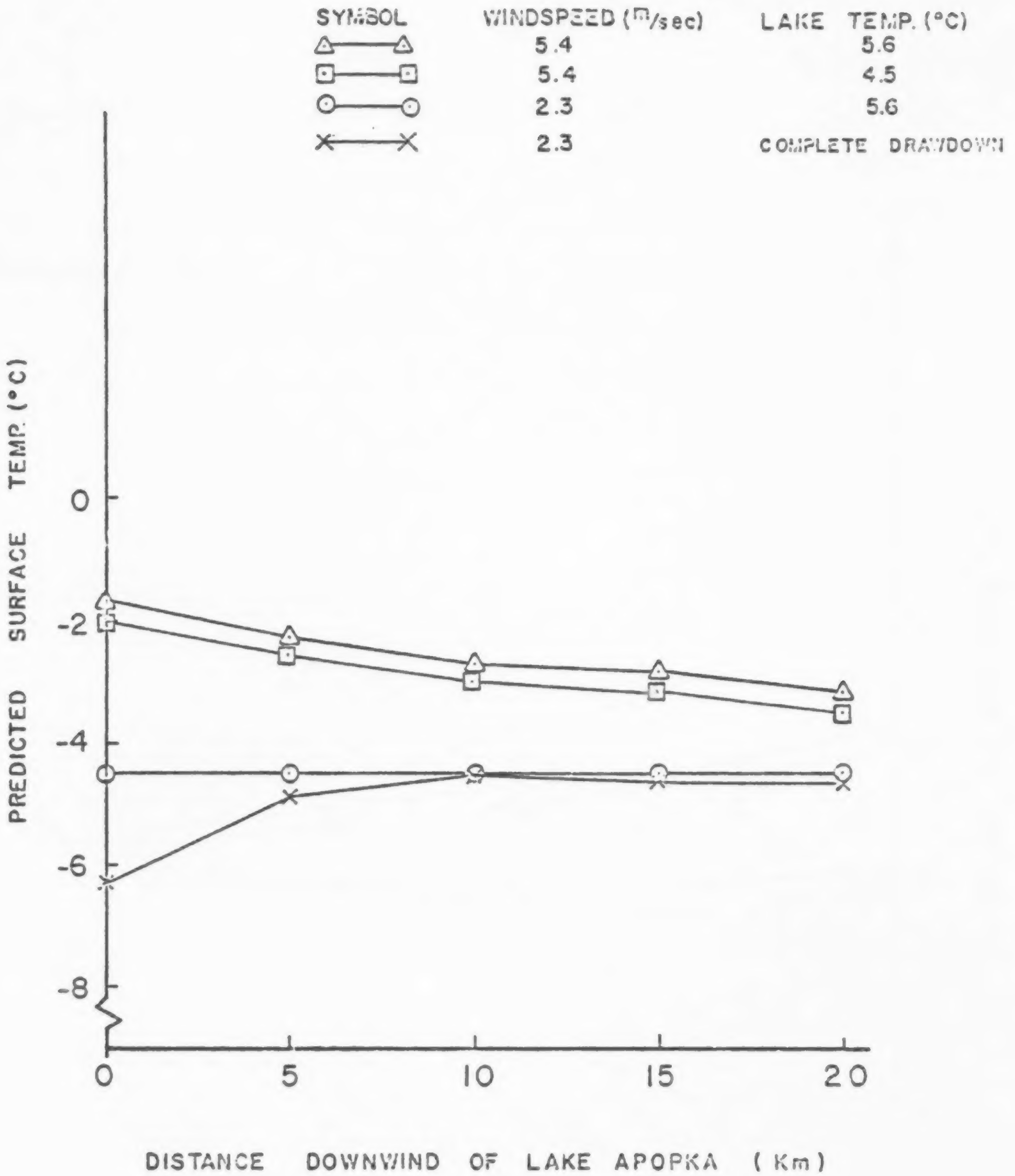


Fig. IV. 4. 2-D Numerical Model results for surface temp.

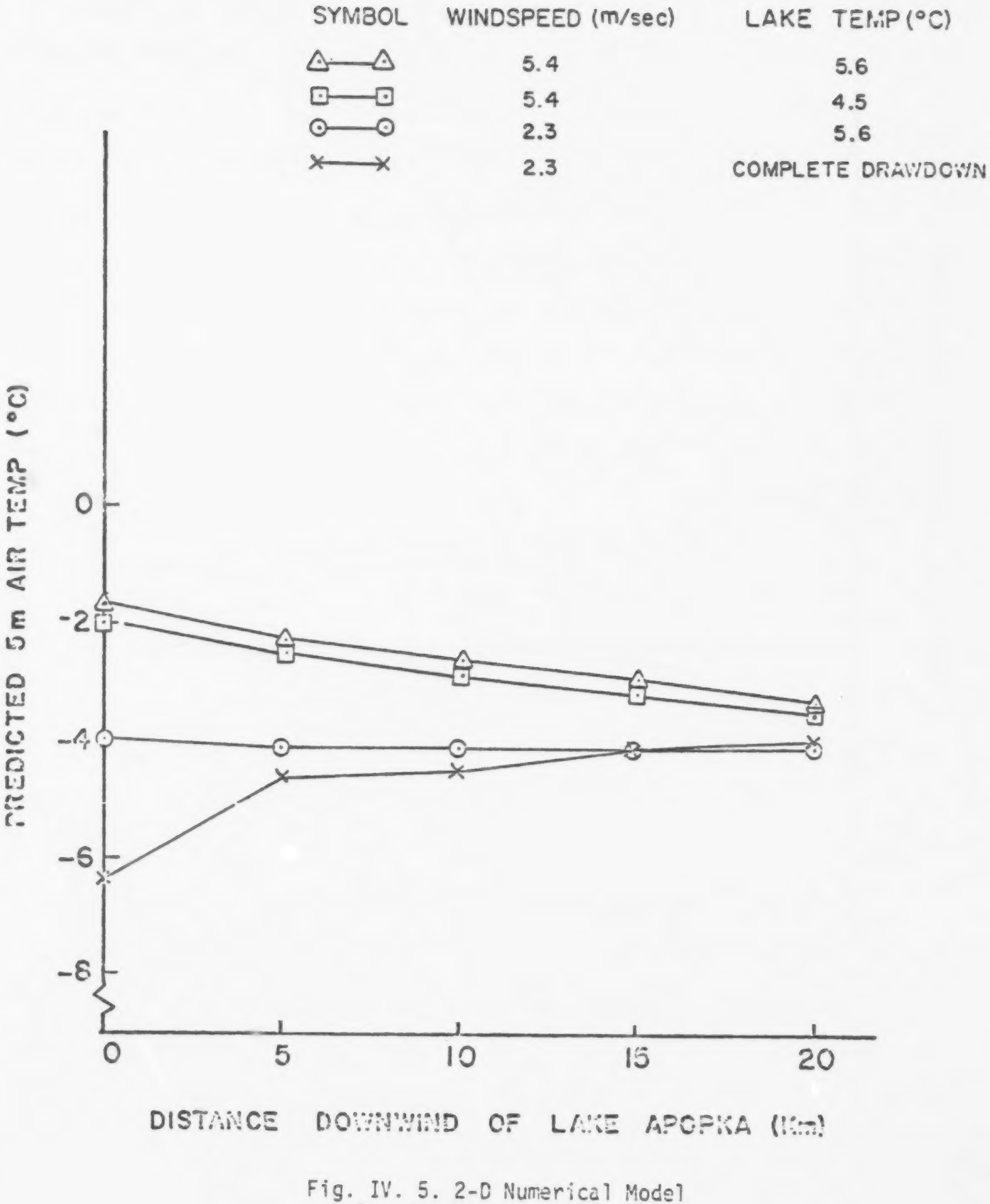


Fig. IV. 5. 2-D Numerical Model
results for 5 m air temp.

V. Conclusions and Recommendations

The results of both the measurements and the numerical models indicate that the lake is a significant aid to citrus growers downwind of Lake Apopka under high wind conditions. In the previous 43 years freeze events have occurred during 25 winters. The models employed in this report have attempted to simulate the passage of a cold front of 2 day duration since 72% of the freeze events lasted 2 days or less (Section II.1). From a meteorological summary of 30 winter seasons (1937 - 1967) at Zellwood [Johnson (1970)], the period of highest probability for the occurrence of these freeze events may be defined. Johnson (1970) indicates that temperatures below 28°F before November 10, 20 and 30 were reported 0, 3 and 23% of the time respectively. After February 28 and March 10, temperatures below 28°F occurred respectively 23 and 0% of the time. Our results indicate then that a minimum average lake level during the period of November 30 to February 28 should be approximately 1m.

With an average depth of 1m the surface area of the lake will remain substantially unchanged; hence, for any given wind direction the land area under protection of the lake should remain the same. Furthermore, the heat capacity of the lake will be sufficient to maintain surface temperatures substantially unchanged from typical lake conditions. This assures that the partition of energy between sensible and latent heat will remain the same. Finally, we note that a lake level of 1m if maintained through back pumping would give growers insurance against the large fluctuations in lake levels that have occurred during winters in the past.

During the drawdown period, we recommend that many of the environmental parameters reported herein be continuously monitored. A minimum data set would include lake temperature, and soil and air temperature north and south of the lake. In the event of severe freeze conditions, data from an aircraft mounted thermal scanner should be acquired to provide a complete picture of temperature patterns south of the lake. An instrumented boat such as that described in this report should be provided to gather meteorological data on the lake. The data from such a study during drawdown would be invaluable for other lake restoration projects.

Acknowledgements: We gratefully acknowledge the technical assistance of Ellen Chen, Jim Georg, and Dr. Robert Sutherland in preparing the results and text of this report.

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